SAN MATEO COUNTYWIDE
Water Pollution
Prevention Program

Appendix A

SMCWPPP Creek Status Monitoring Report

Water Year 2018 (October 2017 – September 2018)

Submitted in compliance with Provision C.8.h.iii of
NPDES Permit No. CAS612008 (Order No. R2-2015-0049)

March 31, 2019

Preface

In early 2010, several members of the Bay Area Stormwater Agencies Association (BASMAA) joined together to form the Regional Monitoring Coalition (RMC), to coordinate and oversee water quality monitoring required by the Municipal Regional National Pollutant Discharge Elimination System (NPDES) Stormwater Permit (in this document the permit is referred to as MRP)[1]. The RMC is comprised of the following participants:

- Alameda Countywide Clean Water Program (ACCWP)
- Contra Costa Clean Water Program (CCCWP)
- San Mateo Countywide Water Pollution Prevention Program (SMCWPPP)
- Santa Clara Valley Urban Runoff Pollution Prevention Program (SCVURPPP)
- Fairfield-Suisun Urban Runoff Management Program (FSURMP)
- City of Vallejo and Vallejo Flood and Wastewater District (Vallejo)

This Creek Status Monitoring Report complies with provision C.8.h.iii of the MRP for reporting of all data in Water Year 2018 (October 1, 2017 through September 30, 2018). Data were collected pursuant to Provisions C.8.d (Creek Status Monitoring) and C.8.g (Pesticides & Toxicity Monitoring) of the MRP. Data presented in this report were produced under the direction of the RMC and the San Mateo Countywide Water Pollution Prevention Program (SMCWPPP) using probabilistic and targeted monitoring designs as described herein.

Consistent with the RMC Creek Status and Long-Term Trends Monitoring Plan (BASMAA 2012), monitoring data were collected in accordance with the most recent versions of the BASMAA RMC Quality Assurance Project Plan (QAPP; BASMAA, 2016a) and BASMAA RMC Standard Operating Procedures (SOPs; BASMAA, 2016b). Where applicable, monitoring data were derived using methods comparable with methods specified by the California Surface Water Ambient Monitoring Program (SWAMP) Quality Assurance Program Plan (QAPrP)[2]. Data presented in this report were also submitted in electronic SWAMP-comparable formats by SMCWPPP to the San Francisco Bay Regional Water Quality Control Board on behalf of San Mateo County Permittees and pursuant to Provision C.8.h.ii of the MRP.

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[1] The San Francisco Bay Regional Water Quality Control Board (SFRWQCB or Regional Water Board) issued the MRP to 76 cities, counties and flood control districts (i.e., Permittees) in the Bay Area on October 14, 2009 (SFRWQCB 2009). On November 19, 2015, the Regional Water Board updated and reissued the MRP (SFRWQCB 2015). The BASMAA programs supporting MRP Regional Projects include all MRP Permittees as well as the cities of Antioch, Brentwood, and Oakley, which are not named as Permittees under the MRP but have voluntarily elected to participate in MRP-related regional activities.

[2] The current SWAMP QAPrP is available at: https://www.waterboards.ca.gov/water_issues/programs/swamp/qapp/swamp_QAPrP_2017_Final.pdf

List of Acronyms

ACCWP	Alameda Countywide Clean Water Program
AFDM	Ash Free Dry Mass
AFS	American Fisheries Society
ASCI	Algae Stream Condition Index
BASMAA	Bay Area Stormwater Management Agency Association
BMI	Benthic Macroinvertebrate
C/CAG	City/County Association of Governments
CCCWP	Contra Costa Clean Water Program
CDFW	California Department of Fish and Wildlife
COLD	Cold Freshwater Habitat
CSCI	California Stream Condition Index
DO	Dissolved Oxygen
DPR	Department of Pesticide Regulation
EDD	Electronic Data Delivery
FSURMP	Fairfield Suisun Urban Runoff Management Program
GIS	Geographic Information System
GRTS	Generalized Random Tessellation Stratified
IBI	Index of Biological Integrity
IPI	Index Physical Habitat Integrity
IPM	Integrated Pest Management
LID	Low Impact Development
MDL	Method Detection Limit
MIGR	Fish Migration
MPC	Monitoring and Pollutants of Concern Committee
MPN	Most Probable Number
MRP	Municipal Regional Permit
MS4	Municipal Separate Storm Sewer System
MUN	Municipal Beneficial Use
MWAT	Maximum Weekly Average Temperature
NPDES	National Pollutant Discharge Elimination System
NT	Non-Target
O/E	Observed to Expected
PAH	Polycyclic Aromatic Hydrocarbons

PCBs	Polychlorinated Biphenyls
PEC	Probable Effects Concentrations
PHAB	Physical Habitat Assessments
pMMI	Predictive Multimetric Index
PSA	Perennial Streams Assessment
QAPP	Quality Assurance Project Plan
QAPrP	Quality Assurance Program Plan
QA/QC	Quality Assurance/Quality Control
RARE	Preservation of Rare and Endangered Species
RM	Reporting Module
RMC	Regional Monitoring Coalition
RWB	Reachwide Benthos
SCCWRP	Southern California Coastal Water Research Project
SCVURPPP	Santa Clara Valley Urban Runoff Pollution Prevention Program
SFRWQCB	San Francisco Bay Regional Water Quality Control Board
SMC	Southern California Monitoring Coalition
SMCWPPP	San Mateo County Water Pollution Prevention Program
SOP	Standard Operating Protocol
SPWN	Fish Spawning
SRP	Stormwater Resource Plan
SSID	Stressor/Source Identification
SWAMP	Surface Water Ambient Monitoring Program
SWPP	Surface Water Protection Program
TEC	Threshold Effects Concentrations
TMDL	Total Maximum Daily Load
TNS	Target Non-Sampleable
TOC	Total Organic Carbon
TS	Target Sampleable
TU	Toxicity Unit
UCMR	Urban Creeks Monitoring Report
USEPA	Environmental Protection Agency
WARM	Warm Freshwater Habitat
WQO	Water Quality Objective
WY	Water Year

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1.0 Introduction

This Creek Status Monitoring Report was prepared by the San Mateo Countywide Water Pollution Prevention Program (SMCWPPP or Program). SMCWPPP is a program of the City/County Association of Governments (C/CAG) of San Mateo County. Each incorporated city and town in the county and the County of San Mateo share a common National Pollutant Discharge Elimination System (NPDES) stormwater permit for Bay Area municipalities referred to as the Municipal Regional Permit (MRP). The MRP was first adopted by the San Francisco Regional Water Quality Control Board (SFRWQCB or Regional Water Board) on October 14, 2009 as Order R2-2009-0074 (SFRWQCB 2009; referred to as MRP 1.0). On November 19, 2015, the Regional Water Board updated and reissued the MRP as Order R2-2015-0049 (SFRWQCB 2015; referred to as MRP 2.0). This report fulfills the requirements of Provision C.8.h.iii of the MRP for comprehensively interpreting and reporting all Creek Status and Pesticides & Toxicity monitoring data collected during the foregoing October 1 – September 30 (i.e., Water Year 2018) [3]. Data were collected pursuant to water quality monitoring requirements in Provisions C.8.d (Creek Status Monitoring) and C.8.g (Pesticides & Toxicity Monitoring) of the MRP. Monitoring data presented in this report were submitted electronically to the Regional Water Board by SMCWPPP and may be obtained via the San Francisco Bay Area Regional Data Center of the California Environmental Data Exchange Network (CEDEN).[4]

Sections of this report are organized according to the following topics:

- **Section 1.0** – Introduction including overview of the Program goals, background, monitoring approach, and statement of data quality
- **Section 2.0** – Biological condition assessment and stressor analysis at probabilistic sites
- **Section 3.0** – Continuous water quality monitoring (temperature, general water quality)
- **Section 4.0** – Pathogen indicators
- **Section 5.0** – Chlorine monitoring
- **Section 6.0** – Pesticides & Toxicity monitoring
- **Section 7.0** – Conclusions and recommendations

[3] Monitoring data collected pursuant to other C.8 provisions (e.g., Pollutants of Concern Monitoring, Stressor/Source Identification Monitoring Projects) are reported in the SMCWPPP Urban Creeks Monitoring Report (UCMR) for WY 2018 to which this Creek Status Monitoring Report is appended.

[4] http://water100.waterboards.ca.gov/ceden/sfei.shtml

1.1 Monitoring Goals

Provision C.8.d of the MRP requires Permittees to conduct creek status monitoring that is intended to answer the following management questions:

1. ***Are water quality objectives, both numeric and narrative, being met in local receiving waters, including creeks, rivers, and tributaries?***
2. ***Are conditions in local receiving water supportive of or likely supportive of beneficial uses?***

The first management question is addressed primarily through the evaluation of probabilistic and targeted monitoring data with respect to the triggers defined in the MRP. (A summary of trigger exceedances observed for each site is presented in Table 7.1.) Sites where triggers are exceeded may indicate potential impacts to aquatic life or other beneficial uses and are considered for future evaluation of Stressor/Source identification (SSID) projects.

The second management question is addressed by assessing indicators of beneficial uses. For example, the indices of biological integrity based on benthic macroinvertebrate and algae data are direct measures of aquatic life beneficial uses. Continuous monitoring data (temperature, dissolved oxygen, pH, and specific conductance) are evaluated with respect to COLD and WARM Beneficial Uses. Pathogen indicator data are used to assess REC-1 (water contact recreation) Beneficial Uses.

Creek Status and Pesticides & Toxicity monitoring parameters, methods, occurrences, durations and minimum number of sampling sites are described in Provisions C.8.d and C.8.g of the MRP, respectively. The monitoring requirements in the 2015 MRP are similar to the 2009 MRP requirements (which began implementation on October 1, 2011) and build upon earlier monitoring conducted by SMCWPPP. Creek Status and Pesticides & Toxicity monitoring is coordinated through the Regional Monitoring Coalition (RMC). Monitoring results are evaluated to determine whether triggers are met and further investigation is warranted as a potential Stressor/Source Identification (SSID) Project, as described in Provision C.8.e of the MRP. Results of Creek Status Monitoring conducted in Water Years 2012 through 2017 were submitted in prior reports (SMCWPPP 2018, SMCWPPP 2017, SMCWPPP 2016, SMCWPPP 2015, SMCWPPP 2014).

1.2 Regional Monitoring Coalition

Provision C.8.a (Compliance Options) of the MRP allows Permitees to address monitoring requirements through a regional collaborative effort, their Stormwater Program, and/or individually. The RMC was formed in early 2010 as a collaboration among a number of the Bay Area Stormwater Management Agencies Association (BASMAA) members and MRP Permittees (Table 1.1) to develop and implement a regionally coordinated water quality monitoring program to improve stormwater management in the region and address water quality monitoring required by the MRP[5]. Implementation of the RMC's Creek Status and Long-Term Trends Monitoring Plan (BASMAA 2012) allows Permittees and the Regional Water Board to improve their ability

[5] The San Francisco Bay Regional Water Quality Control Board (SFRWQCB) issued the first five-year MRP to 76 cities, counties and flood control districts (i.e., Permittees) in the Bay Area on October 14, 2009 (SFRWQCB 2009). The BASMAA programs supporting MRP Regional Projects include all MRP Permittees as well as the cities of Antioch, Brentwood, and Oakley which are not named as Permittees under the MRP but have voluntarily elected to participate in MRP-related regional activities.

to collectively answer core management questions in a cost-effective and scientifically rigorous way. Participation in the RMC is facilitated through the BASMAA Monitoring and Pollutants of Concern (MPC) Committee.

Table 1.1. Regional Monitoring Coalition participants.

Stormwater Programs	RMC Participants
Santa Clara Valley Urban Runoff Pollution Prevention Program (SCVURPPP)	Cities of Campbell, Cupertino, Los Altos, Milpitas, Monte Sereno, Mountain View, Palo Alto, San Jose, Santa Clara, Saratoga, Sunnyvale, Los Altos Hills, and Los Gatos; Santa Clara Valley Water District; and, Santa Clara County
Alameda Countywide Clean Water Program (ACCWP)	Cities of Alameda, Albany, Berkeley, Dublin, Emeryville, Fremont, Hayward, Livermore, Newark, Oakland, Piedmont, Pleasanton, San Leandro, and Union City; Alameda County; Alameda County Flood Control and Water Conservation District; and, Zone 7
Contra Costa Clean Water Program (CCCWP)	Cities of Antioch, Brentwood, Clayton, Concord, El Cerrito, Hercules, Lafayette, Martinez, Oakley, Orinda, Pinole, Pittsburg, Pleasant Hill, Richmond, San Pablo, San Ramon, Walnut Creek, Danville, and Moraga; Contra Costa County; and, Contra Costa County Flood Control and Water Conservation District
San Mateo County Wide Water Pollution Prevention Program (SMCWPPP)	Cities of Belmont, Brisbane, Burlingame, Daly City, East Palo Alto, Foster City, Half Moon Bay, Menlo Park, Millbrae, Pacifica, Redwood City, San Bruno, San Carlos, San Mateo, South San Francisco, Atherton, Colma, Hillsborough, Portola Valley, and Woodside; San Mateo County Flood Control District; and, San Mateo County
Fairfield-Suisun Urban Runoff Management Program (FSURMP)	Cities of Fairfield and Suisun City
Vallejo Permittees	City of Vallejo and Vallejo Flood and Wastewater District

The goals of the RMC are to:

1. Assist Permittees in complying with requirements in MRP Provision C.8 (Water Quality Monitoring);

2. Develop and implement regionally consistent creek monitoring approaches and designs in the Bay Area, through the improved coordination among RMC participants and other agencies (e.g., Regional Water Board) that share common goals; and

3. Stabilize the costs of creek monitoring by reducing duplication of effort and streamlining reporting.

The RMC's monitoring strategy for complying with Creek Status monitoring is described in the RMC Creek Status and Long-Term Trends Monitoring Plan (BASMAA 2012). The strategy includes regional ambient/probabilistic monitoring and local "targeted" monitoring. The combination of these two components allows each individual RMC participating program to assess the status of beneficial uses in local creeks within its jurisdictional area, while also contributing data to answer management questions at the regional scale (e.g., differences between aquatic life condition in urban and non-urban creeks). The 2015 MRP, specifically prescribes the probabilistic/targeted approach and most of the other details of the RMC Creek Status and Long-Term Trends Monitoring Plan. Table 1.2 provides a list of which parameters are included in the probabilistic and targeted programs in the 2015 MRP. This report includes data collected in San Mateo County under both monitoring components. Data are organized into report sections that reflect the format of monitoring requirements in the MRP.

Table 1.2. Creek Status Monitoring parameters in compliance with MRP Provisions C.8.d (Creek Status Monitoring) and C.8.g (Pesticides & Toxicity Monitoring) and associated monitoring component.

Monitoring Elements	Monitoring Component		Report Section
	Regional Ambient (Probabilistic)	Local (Targeted)	
Creek Status Monitoring (C.8.d)			
Bioassessment & Physical Habitat Assessment	X	(X)[1]	2.0
Nutrients	X	(X)[1]	2.0
General Water Quality (Continuous)		X	3.0
Temperature (Continuous)		X	3.0
Pathogen Indicators		X	4.0
Chlorine	X	(X)[2]	5.0
Pesticides & Toxicity Monitoring (C.8.g)			
Water Toxicity		X	6.0
Water Chemistry		X	6.0
Sediment Toxicity		X	6.0
Sediment Chemistry		X	6.0

Notes:
[1] Provision C.8.d.i.(6) allows for up to 20% of sample locations to be selected on a targeted basis.
[2] Provision C.8.d.ii.(2) provides options for probabilistic or targeted site selection. In WY 2018, chlorine was measured at probabilistic sites.

1.3 Monitoring and Data Assessment Methods

1.3.1 Monitoring Methods

Water quality data were collected in accordance with California Surface Water Ambient Monitoring Program (SWAMP) comparable methods and procedures described in the BASMAA RMC Standard Operating Procedures (SOPs; BASMAA 2016b) and the associated Quality Assurance Project Plan (QAPP; BASMAA 2016a). These documents are updated as needed to maintain their currency and optimal applicability. Where applicable, monitoring data were collected using methods comparable to those specified by the SWAMP Quality Assurance Program Plan (QAPrP)[6], and were submitted in SWAMP-compatible format to the Regional Water Board. The SOPs were developed using a standard format that describes health and safety cautions and considerations, relevant training, site selection, and sampling methods/procedures, including pre-fieldwork mobilization activities to prepare equipment, sample collection, and de-mobilization activities to preserve and transport samples.

[6] The current SWAMP QAPrP is available at: https://www.waterboards.ca.gov/water_issues/programs/swamp/qapp/swamp_QAPrP_2017_Final.pdf

1.3.2 Laboratory Analysis Methods

RMC participants, including SMCWPPP, agreed to use the same laboratories for individual parameters (except pathogen indicators), developed standards for contracting with the labs, and coordinated quality assurance samples. All samples collected by RMC participants that were sent to laboratories for analysis were analyzed and reported per SWAMP-comparable methods as described in the RMC QAPP (BASMAA 2016a). Analytical laboratory methods, reporting limits and holding times for chemical water quality parameters are also described in BASMAA (2016a). Analytical laboratory contractors included:

- BioAssessment Services, Inc. – Benthic macroinvertebrate (BMI) identification
- EcoAnalysts, Inc. – Algae identification
- CalTest, Inc. – Sediment chemistry, nutrients, chlorophyll a, ash free dry mass
- Pacific EcoRisk, Inc. - Water and sediment toxicity
- Alpha Analytical – Pathogen indicators

1.3.3 Data Analysis Methods

Monitoring data generated during WY 2018 were analyzed and evaluated to identify potential stressors that may be contributing to degraded or impacted biological conditions, including exceedances of water quality objectives (WQOs). Creek Status Monitoring and Pesticides & Toxicity Monitoring data must be evaluated with respect to numeric thresholds (i.e., triggers), specified in the "Followup" sections in Provision C.8.d and C.8.g of the MRP (SFRWQCB 2015) that, if not met, require consideration for further evaluation as part of a Stressor/Source Identification project. SSID projects are intended to be oriented toward taking action(s) to alleviate stressors and reduce sources of pollutants. A stepwise process for conducting SSID projects is described in Provision C.8.e.iii.

In compliance with Provision C.8.e.i of the MRP, all monitoring results exceeding trigger thresholds are added to a list of candidate SSID projects that will be maintained throughout the permit term. Follow-up SSID projects are selected from this list.

1.4 Setting

There are 34 watersheds in San Mateo County draining an area of about 450 square miles. The San Mateo Range, which runs north/south, divides the county roughly in half. The eastern half ("Bayside") drains to San Francisco Bay and is characterized by relatively flat, urbanized areas along the Bay. The western half ("coastside") drains to the Pacific Ocean and consists of approximately 50 percent parkland and open space, with agriculture and relatively small urban areas.

The complete list of probabilistic and targeted monitoring sites sampled by SMCWPPP in WY 2018 in compliance with Provisions C.8.d (Creek Status Monitoring) and C.8.g (Pesticides and Toxicity Monitoring) is presented in Table 1.3. Monitoring locations with monitoring parameter(s) are mapped in Figure 1.1. Probabilistic station numbers, generated from the RMC Sample Frame, are provided for all bioassessment locations. Targeted stations numbers, based on SWAMP station numbering methods (BASMAA 2016b), are provided for all targeted monitoring sites.

Table 1.3. Sites and parameters monitored in WY 2018 in San Mateo County.

Map ID [1]	Station ID	Bayside or Coastside	Watershed	Creek Name	Land Use	Latitude	Longitude	Probabilistic	Targeted				
								Bioassessment, Nutrients, General WQ	Chlorine	Pesticides & Toxicity	Temp [2]	Cont WQ [3]	Pathogen Indicators
584	202R00584	Coastal	Pilarcitos Creek	Pilarcitos Creek	NU	37.49547	-122.38512	X	X				
614	202R00614	Coastal	Pescadero Creek	Pescadero Creek	NU	37.27410	-122.28860	X	X				
3404	202R03404	Coastal	San Pedro Creek	San Pedro Creek	U	37.58203	-122.48719	X	X				
3656	202R03656	Coastal	Pilarcitos Creek	Pilarcitos Creek	U	37.46781	-122.42269	X	X				
3880	202R03880	Coastal	San Gregorio Cr	La Honda Creek	U	37.38759	-122.27219	X	X				
3916	202R03916	Coastal	San Pedro Creek	San Pedro Creek	U	37.59144	-122.50333	X	X				
3508	204R03508	Bayside	Mills Creek	Mills Creek	U	37.59105	-122.37406	X	X				
3528	204R03528	Bayside	San Mateo Creek	San Mateo Creek	U	37.54808	-122.34661	X	X				
3624	205R03624	Bayside	San Francisquito Cr	Bear Creek	U	37.41883	-122.26498	X	X				
3864	205R03864	Bayside	San Francisquito Cr	Hamms Gulch	U	37.36498	-122.22906	X	X				
5	202SPE005	Coastside	San Pedro Creek	San Pedro Creek	U	37.59441	-122.50520			X			
10	204COR010	Bayside	Cordilleras Creek	Cordilleras Creek	U	37.47977	-122.25986			X			
138	202PES138	Coastside	Pescadero Creek	Pescadero Creek	NU	37.27410	-122.28860						X
142	202PES142	Coastside	Pescadero Creek	McCormick Creek	NU	37.27757	-122.28635						X
144	202PES144	Coastside	Pescadero Creek	Pescadero Creek	NU	37.27592	-122.28550						X
150	202PES150	Coastside	Pescadero Creek	Jones Gulch	NU	37.27424	-122.26811						X
154	202PES154	Coastside	Pescadero Creek	Pescadero Creek	NU	37.27446	-122.26798						X
19	202SPE019	Coastside	San Pedro Creek	San Pedro Creek	U	37.58853	-122.49943				X		
40	202SPE040	Coastside	San Pedro Creek	San Pedro Creek	U	37.58200	-122.48708				X	X	
50	202SPE050	Coastside	San Pedro Creek	San Pedro Creek	U	37.58198	-122.47819				X		
70	202SPE070	Coastside	San Pedro Creek	San Pedro Creek	NU	37.57974	-122.47371				X	X	
85	202SPE085	Coastside	San Pedro Creek	San Pedro Creek	NU	37.57826	-122.47156				X		

U = urban, NU = non-urban

[1] Map ID applies to Figure 3.1.

[2] Temperature monitoring was conducted continuously (i.e., hourly) April through September.

[3] Continuous water quality monitoring (temperature, dissolved oxygen, pH, specific conductivity) was conducted during two 2-week periods (spring and late summer).

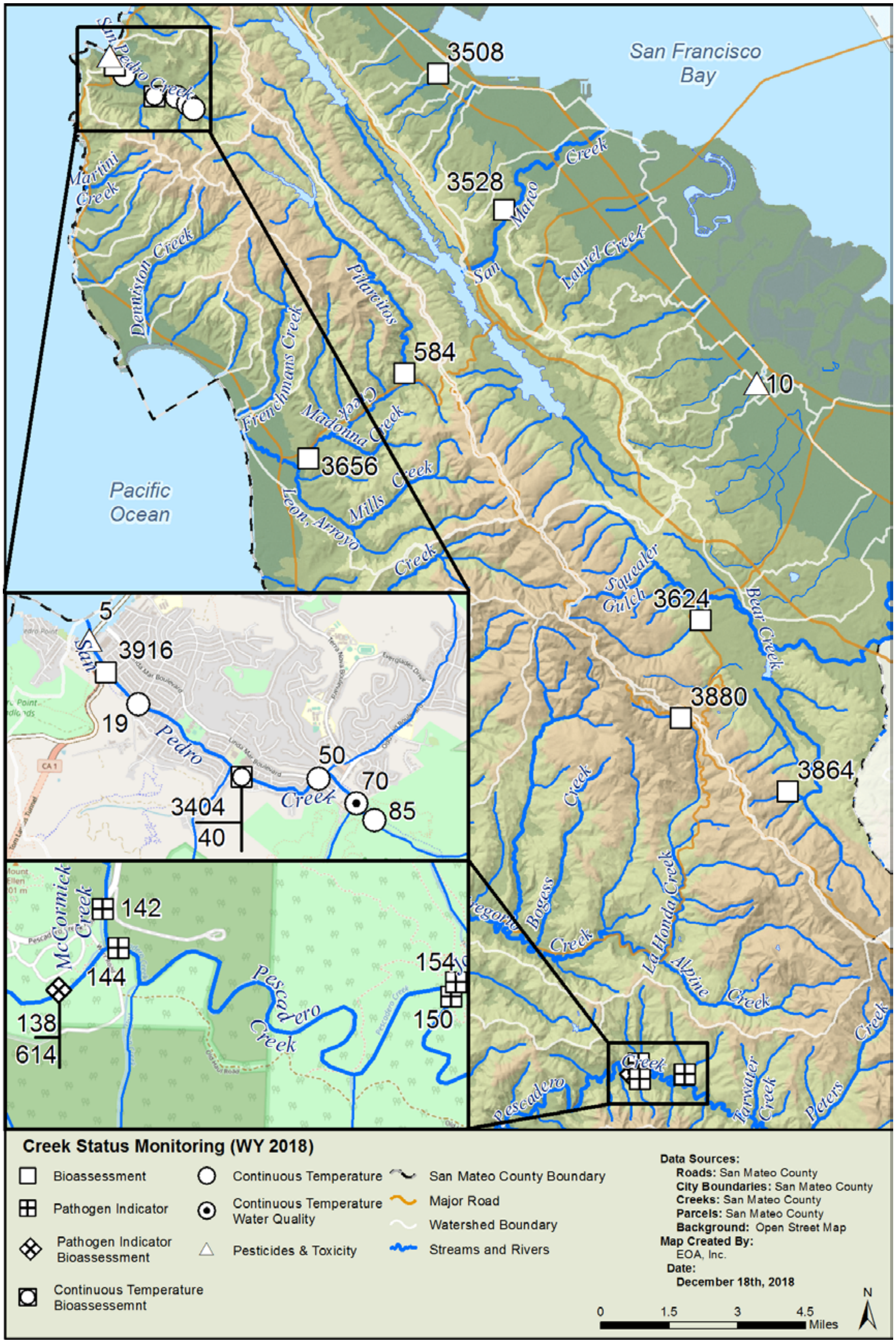

Figure 1.1. Map of SMCWPPP sites monitored in WY 2018.

1.4.1 Designated Beneficial Uses

Beneficial Uses in San Mateo County creeks are designated by the Regional Water Board for specific water bodies and generally apply to all its tributaries. Uses include aquatic life habitat, recreation, agriculture, and municipal supply. Table 1.4 lists Beneficial Uses designated by the SFRWQCB (2017) for water bodies monitored by SMCWPPP in WY 2018.

Table 1.4. Creeks Monitored by SMCWPPP in WY 2018 and their Beneficial Uses (SFRWQCB 2017).

Waterbody	AGR	MUN	FRSH	GWR	IND	PROC	COMM	SHELL	COLD	EST	MAR	MIGR	RARE	SPWN	WARM	WILD	REC-1	REC-2	NAV
Coastside Creeks																			
Pilarcitos Creek	E	E							E			E	E	E	E	E	E	E	
Pescadero Creek	E	E							E			E	E	E	E	E	E	E	
San Pedro Creek		E							E			E	E	E	E	E	E	E	
La Honda Creek									E			E	E	E	E	E	E	E	
Bayside Creeks																			
San Mateo Creek			E						E			E	E	E	E	E	E	E	
Bear Creek									E			E	E	E	E	E	E	E	
Hamms Gulch[1]									E			E	E	E	E	E	E	E	
Mills Creek															E	E	E	E	
Cordilleras Creek															E	E	E	E	

Notes:
[1] No Beneficial Uses listed specifically for waterbody. Table shows Beneficial Uses for receiving waterbody (Bear Creek).
E = Existing Use, P = Potential Use, L = Limited Use

AGR = Agricultural Supply
COLD = Cold Fresh Water Habitat
FRSH = Freshwater Replenishment
GWR - Groundwater Recharge
MIGR = Fish Migration
MUN = Municipal and Domestic Water
SHELL = Shellfish Harvesting

IND = Industrial Service Supply
EST = Estuarine
NAV = Navigation
RARE= Preservation of Rare and Endangered Species
REC-1 = Water Contact Recreation
SPWN = Fish Spawning

COMM = Commercial, and Sport Fishing
REC-2 = Non-contact Recreation
WARM = Warm Freshwater Habitat
WILD = Wildlife Habitat
PROC = Industrial Process Supply
MAR = Marine Habitat

1.4.2 Climate

San Mateo County experiences a Mediterranean-type climate with cool, wet winters and hot, dry summers. The area is characterized by microclimates created by topography, ocean currents, fog exposure, and onshore winds. The wet season typically extends from October through April with local long-term, mean annual precipitation ranging from 20 inches near the Bay to over 40 inches along the highest ridges of the San Mateo Mountain Range (PRISM Climate Group 30-year normals, 1981-2010[7]). Figure 1.2 illustrates the geographic variability of mean annual precipitation in the area. It is important to understand that mean annual precipitation depths are statistically calculated or modeled; actual measured precipitation in a given year rarely equals

[7] http://www.prism.oregonstate.edu/normals/

the statistical average. Figure 1.3 illustrates the temporal variability in annual precipitation measured at the San Francisco International Airport (SFO) from WY 1946 to WY 2018. This record illustrates that extended periods of drought are common and often punctuated by above average years. Creek Status Monitoring in compliance with the MRP began in WY 2012 which was the first year of a severe statewide drought that persisted through WY 2016. WY 2018 rainfall was below average at SFO but it was preceded by a wet year in WY 2017.

The overall Bay Area climate and the specific conditions within any given year are influenced by global climate change. The Climate Change Assessment report for the Bay Area highlights several impacts of climate change that are already being felt: the Bay Area's average annual maximum temperature increased by nearly 1°C from 1950 – 2005, coastal fog along the coast may be less frequent, sea level in the Bay Area has risen over 8 inches (Ackerly et al. 2018). These changes are projected to increase significantly in the coming decades. As a consequence, heat extremes, high year-to-year variability in precipitation, droughts, intense storms, and other events will also increase.

Climate patterns (e.g., extended droughts) and individual weather events (e.g., extreme storms, hot summers) influence biological communities (i.e., vegetation, wildlife) and their surrounding physical habitat and water quality. They should therefore be considered when evaluating the type of data collected by the Creek Status Monitoring Program. For example, periods of drought (rather than individual dry years) can result in changes in riparian and upland vegetation communities. Long drought periods are associated with increased streambed sedimentation which can persist directly or indirectly for many years, depending on the occurrence and magnitude of flushing flow events. Furthermore, in response to prolonged drought, the relative proportion of pool habitat can increase at the expense of riffle habitat.

It is uncertain what effect these factors have on indices of biotic integrity (IBIs) that are calculated using data collected by the Creek Status Monitoring Program, such as benthic macroinvertebrates or algae. A study evaluating 20 years of bioassessment data collected in northern California showed that, although benthic macroinvertebrate taxa with certain traits may be affected by dry (and wet) years and/or warm (and cool) years, IBIs based on these organisms appear to be resilient (Mazor et al. 2009, Lawrence et al. 2010). However, this study did not specifically examine the impact of longer *periods* of extended drought or heat on IBIs, which would require analysis of a dataset with a much longer period of record. The Herbst Lab at the Sierra Nevada Aquatic Research Laboratory, University of California Santa Barbara is currently exploring how changing climate affects Sierra Nevada stream ecosystems.

Figure 1.2. Average annual precipitation in San Mateo County, modeled by the PRISM Climate Group for the period of 1981-2010.

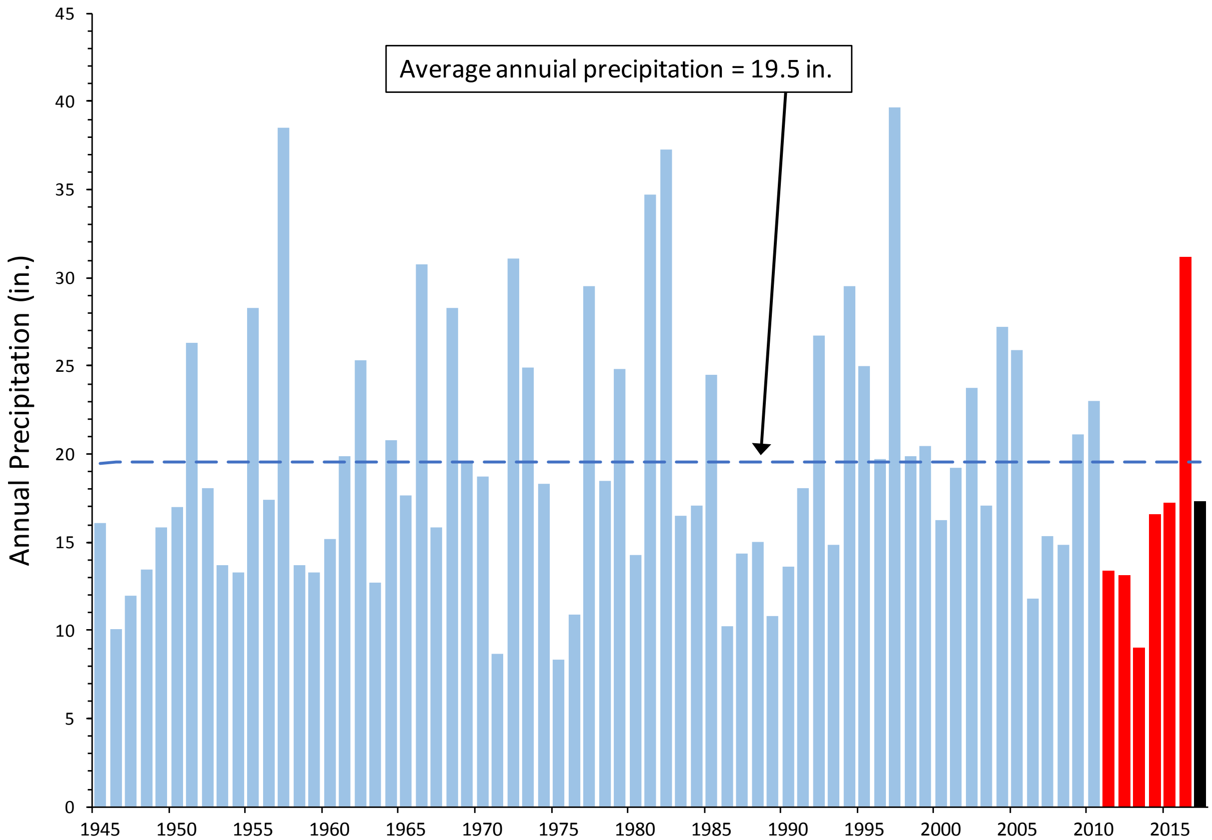

Figure 1.3. Annual rainfall recorded at the San Francisco International Airport, WY 1946 – WY 2018.

1.5 Statement of Data Quality

A comprehensive Quality Assurance/Quality Control (QA/QC) program was implemented by SMCWPPP covering all aspects of the probabilistic and targeted monitoring. In general QA/QC procedures were implemented as specified in the BASMAA RMC QAPP (BASMAA, 2016a), and monitoring was performed according to protocols specified in the BASMAA RMC SOPs (BASMAA, 2016b), and in conformity with methods specified by the SWAMP QAPrP[8]. A detailed QA/QC report is included as Attachment 1.

Based on the QA/QC review, no WY 2018 data were rejected, but some data were flagged. Overall, WY 2018 data met QA/QC objectives.

[8] The current SWAMP QAPrP is available at: http://www.waterboards.ca.gov/water_issues/programs/swamp/docs/qapp/swamp_qapp_master090108a.pdf

2.0 Biological Condition Assessment

2.1 Introduction

In compliance with Creek Status Monitoring Provision C.8.d.i, SMCWPPP conducted bioassessment monitoring in WY 2018. All bioassessment monitoring was performed at sites selected randomly using the probabilistic monitoring design[9]. The probabilistic monitoring design allows each individual RMC participating program to objectively assess stream ecosystem conditions within its program area (County boundary) while contributing data to answer regional management questions about water quality and beneficial use condition in San Francisco Bay Area creeks. The survey design provides an unbiased framework for data evaluation that will allow a condition assessment of ambient aquatic life uses within known estimates of precision. The monitoring design was developed to address the management questions for both RMC participating county and overall RMC area described below:

1. *What is the condition of aquatic life in creeks in the RMC area; are water quality objectives met and are beneficial uses supported?*
   - i. *What is the condition of aquatic life in the urbanized portion of the RMC area; are water quality objectives met and are beneficial uses supported?*
   - ii. *What is the condition of aquatic life in RMC participant counties; are water quality objectives met and are beneficial uses supported?*
   - iii. *To what extent does the condition of aquatic life in urban and non-urban creeks differ in the RMC area?*
   - iv. *To what extent does the condition of aquatic life in urban and non-urban creeks differ in each of the RMC participating counties?*
2. *What are major stressors to aquatic life in the RMC area?*
   - i. *What are major stressors to aquatic life in the urbanized portion of the RMC area?*
3. *What are the long-term trends in water quality in creeks over time?*

The first question (i.e., *What is the condition of aquatic life in creeks in the RMC?*) is addressed by assessing indicators of aquatic biological health at probabilistic sampling locations. Once a sufficient number of samples have been collected, ambient biological condition can be estimated for streams at a regional scale. Over the past seven years (WY 2012 through WY 2018), SMCWPPP and the Regional Water Board have sampled 80 probabilistic sites in San Mateo County, providing a sufficient sample size to estimate ambient biological condition for urban streams countywide. There are still an insufficient number of samples to accurately assess the biological condition of non-urban streams in the county, or of individual watersheds or smaller jurisdictional areas (i.e., cities).[10]

The second question (i.e., *What are major stressors to aquatic life in the RMC area?*) is addressed by the collection and evaluation of physical habitat and water chemistry data

[9] The option to conduct 20% of bioassessment surveys at targeted sites was not exercised in WY 2018.

[10] For each of the strata, it is necessary to obtain a sample size of at least 30 in order to evaluate the condition of aquatic life within known estimates of precision. This estimate is defined by a power curve from a binomial distribution (BASMAA 2012).

collected at the probabilistic sites, as potential stressors to biological health. In addition, the stressor levels can be compared to biological indicator data through correlation and relative risk analyses. Assessing the extent and relative risk of stressors can help prioritize stressors at a regional scale and inform local management decisions.

The third question (i.e., *What are the long-term trends in water quality in creeks over time?*) is addressed by assessing the change in biological condition over several years. Changes in biological condition over time can help evaluate the effectiveness of management actions. Although, long-term trend analysis for the RMC probabilistic survey will require more than seven years of data collection, preliminary trend analysis of biological condition may be possible for some stream reaches using a combination of historical targeted data with the probabilistic data.

This report presents biological indicator data and potential stressor data collected at ten sites in WY 2018. Data are compared to triggers and water quality objectives identified in the MRP.

A more comprehensive evaluation of regional bioassessment data is presented in the BASMAA RMC 5-Year Bioassessment Report (WY 2012 – WY 2016) (Attachment 2). Summary findings from the report are included in Section 7.1.

2.2 Methods

2.2.1 Probabilistic Survey Design

The RMC probabilistic design was created using the Generalized Random Tessellation Stratified (GRTS) approach developed by the United States Environmental Protection Agency (USEPA) and Oregon State University (Stevens and Olson 2004). GRTS offers multiple benefits for coordinating among monitoring entities, including the ability to develop a spatially balanced design that produces statistically representative data with known confidence intervals. The GRTS approach has been implemented in California by several agencies including the statewide Perennial Streams Assessment (PSA) conducted by Surface Water Ambient Monitoring Program (Ode et al. 2011) and the Southern California Stormwater Monitoring Coalition's (SMC) regional monitoring program conducted by municipal stormwater programs in Southern California (SCCWRP 2007).

Sample sites were selected using the GRTS approach from a sample frame consisting of a creek network geographic information system (GIS) data set within the 3,407-square mile RMC area (BASMAA 2012). The sample frame includes non-tidally influenced perennial and non-perennial creeks within five management units representing areas managed by the stormwater programs associated with the RMC (listed in Table 1.1). There is approximately one site for every stream kilometer in the sample frame. The National Hydrography Plus Dataset (1:100,000) was selected as the creek network data layer to provide consistency with both the Statewide PSA and the SMC, and the opportunity for future data coordination with these programs.

Once the master draw was performed, the list of sites was classified by county and land use (i.e., urban and non-urban) to allow for comparisons between these strata. Urban areas were delineated by combining urban area boundaries and city boundaries defined by the U.S. Census (2000). Non-urban areas were defined as the remainder of the RMC area. Some sites classified as urban fall near the non-urban edge of the city boundaries and have little upstream development. For the purposes of consistency, these urban sites were not re-classified. Therefore, data values within the urban classification represent a wide range of conditions.

The RMC participants weight their annual sampling efforts so that approximately 80% are in in urban areas and 20% in non-urban areas. In addition, between WY 2012 and WY 2015, SWAMP conducted 34 bioassessments throughout the RMC region at non-urban sites selected from the sample frame, including 10 sites in San Mateo County[11].

2.2.2 Site Evaluations

Sites identified in the regional sample draw are evaluated by each RMC participant in chronological order using a two-step process described in RMC Standard Operating Procedure FS-12 (BASMAA 2016b), consistent with the procedure described by Southern California Coastal Water Research Project (SCCWRP) (2012). Each site is evaluated to determine if it meets the following RMC sampling location criteria:

1. The location (latitude/longitude) provided for a site is located on or is within 300 meters of a non-impounded receiving water body[12];
2. Site is not tidally influenced;
3. Site is wadeable during the sampling index period;
4. Site has sufficient flow during the sampling index period to support standard operation procedures for biological and nutrient sampling.
5. Site is physically accessible and can be entered safely at the time of sampling;
6. Site may be physically accessed and sampled within a single day;
7. Landowner(s) grant permission to access the site[13].

In the first step, these criteria were evaluated to the extent possible using a “desktop analysis.” Site evaluations were completed during the second step via field reconnaissance visits. Based on the outcome of site evaluations, sites were classified into one of three categories:

- **Target** – Target sites were grouped into two subcategories:
  - **Target Sampleable (TS)** - Sites that met all seven criteria and were successfully sampled.
  - **Target Non-Sampleable (TNS)** - Sites that met criteria 1 through 4, but did not meet at least one of criteria 5 through 7 were classified as TNS.
- **Non-Target (NT)** - Sites that did not meet at least one of criteria 1 through 4 were classified as non-target status.
- **Unknown (U)** - Sites were classified with unknown status when it could be reasonably inferred either via desktop analysis or a field visit that the site was a valid receiving water body and information for any of the seven criteria was unconfirmed.

All site evaluation information was documented on field forms and entered into a standardized database. The overall percent of sites classified into the three categories can be evaluated to

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[11] SFRWQCB SWAMP staff have indicated that they will not conduct RMC related bioassessment monitoring during MRP 2.0.

[12] The evaluation procedure permits certain adjustments of actual site coordinates within a maximum of 300 meters.

[13] If landowners do not respond to at least two attempts to contact them either by written letter, email, or phone call, permission to access the respective site is effectively considered to be denied.

determine the statistical significance of local and regional average ambient conditions calculated from the multi-year dataset.

2.2.3 Field Sampling Methods

Bioassessment survey methods were consistent with the BASMAA RMC QAPP (BASMAA 2016a) and SOPs (BASMAA 2016b).

In accordance with the RMC QAPP (BASMAA 2016a) bioassessments were planned during the spring index period (approximately April 15 – July 15) with the goal to sample a minimum of 30 days after any significant storm (defined as at least 0.5-inch of rainfall within a 24-hour period). A 30-day grace period allows diatom and soft algae communities to recover from peak flows that may scour benthic algae from the bottom of the stream channel. During WY 2018, there was a small but significant storm on April 8, just prior to the index period; however, field sampling in San Mateo County was conducted between May 14 and May 22, more than 30 days following the storm.

Each bioassessment sampling site consisted of an approximately 150-meter stream reach that was divided into 11 equidistant transects placed perpendicular to the direction of flow. Benthic macroinvertebrate (BMI) and algae samples were collected at 11 evenly spaced transects using the Reachwide Benthos (RWB) method described in the SWAMP SOP (Ode et al. 2016). The most recent SWAMP SOP (i.e., Ode et al. 2016) combines the BMI and algae methods that are referenced in the MRP (Ode et al. 2007, Fetscher et al. 2009), provides additional guidance, and adds two new physical habitat analytes (assess scour and engineered channels). The full suite of physical habitat data was collected within the sample reach using methods described in Ode et al. (2016).

Immediately prior to biological and physical habitat data collection, water samples were collected for nutrients, conventional analytes, ash free dry mass, and chlorophyll a analysis using the Standard Grab Sample Collection Method as described in SOP FS-2 (BASMAA 2016b). Water samples were also collected and analyzed in the field for free and total chlorine using a Pocket Colorimeter™ II and DPD Powder Pillows according to SOP FS-3 (BASMAA 2016b) (see Section 5.0 for chlorine monitoring results). In addition, general water quality parameters (dissolved oxygen, pH, specific conductivity and temperature) were measured at or near the centroid of the stream flow using a pre-calibrated multi-parameter probe.

Biological and water samples were sent to laboratories for analysis. The laboratory analytical methods used for BMIs followed Woodward et al. (2012), using the Southwest Association of Freshwater Invertebrate Taxonomists (SAFIT) Level 1 Standard Taxonomic Level of Effort, with the additional effort of identifying chironomids (midges) to subfamily/tribe instead of family (Chironomidae). Soft algae and diatom samples were analyzed following SWAMP protocols (Stancheva et al. 2015). The taxonomic resolution for all data was compared SWAMP master taxonomic list. All taxa identified in samples collected were on the SWAMP Master List and are included in the data submittal for WY 2018.

2.2.4 Data Analysis

BMI and algae data were analyzed to assess the biological condition (i.e., aquatic life Beneficial Uses) of the sampled reaches using condition index scores. Physical habitat data were used to characterize physical habitat conditions using a newly developed multimetric index scoring tool. Physical habitat and water chemistry data were also evaluated as potential stressors to biological health using triggers and water quality objectives identified in the MRP (see Stressor Variable section below). Data analysis methods are described below.

Biological Indicators

Benthic Macroinvertebrates

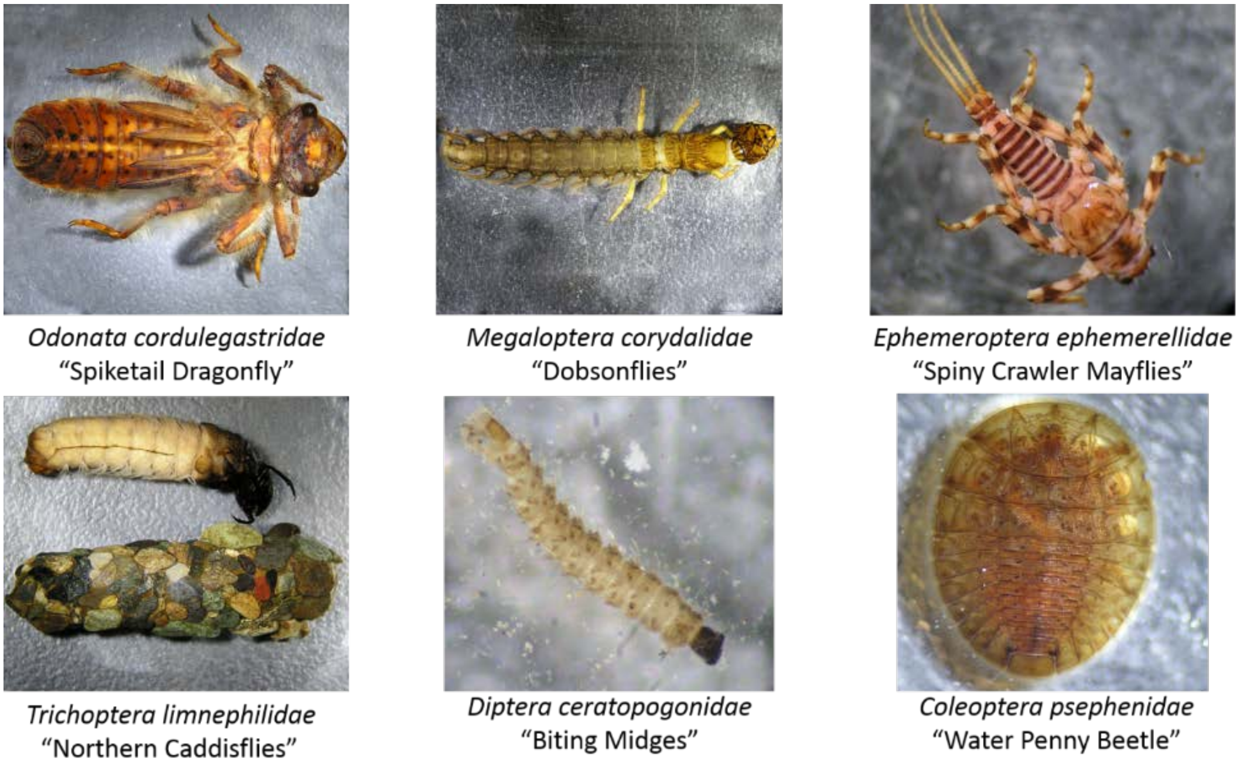
The benthic (i.e., bottom-dwelling) macroinvertebrates collected through this monitoring program are organisms that live on, under, and around the rocks and sediment in the stream bed. Examples include dragonfly and stonefly larvae, snails, worms, and beetles (Figure 2.1). Each BMI species has a unique response to water chemistry and physical habitat condition. Some are relatively sensitive to poor habitat and pollution; others are more tolerant. Therefore, the abundance and variety of BMIs in a stream indicates the biological condition of the stream.

The California Stream Condition Index (CSCI) is an assessment tool that was developed by the State Water Resources Control Board (State Water Board) to support the development of California's statewide Biological Integrity Plan[14]. The CSCI translates benthic macroinvertebrate data into an overall measure of stream health. The CSCI was developed using a large reference data set that represents the full range of natural conditions in California and site-specific models for predicting biological communities. The CSCI combines two types of indices: 1) taxonomic completeness, as measured by the ratio of observed-to-expected taxa (O/E); and 2) ecological structure and function, measured as a predictive multimetric index (pMMI) that is based on reference conditions. The CSCI score is computed as the average of the sum of the O/E and pMMI.

CSCI scores for each station are calculated using a combination of biological and environmental data following methods described in Rehn et al. (2015). Biological data consist of the BMI data collected and analyzed using the protocols described in the previous section. Environmental predictor data are generated in GIS using drainage areas upstream of each BMI sampling location. The environmental predictors and BMI data were formatted into comma delimited files and used as input for the RStudio statistical package and the necessary CSCI program scripts, developed by Southern California Coastal Water Research Project (SCCWRP) staff (Mazor et al. 2016).

The State Water Board is continuing to evaluate the performance of CSCI in a regulatory context. In the current MRP, the Regional Water Board defined a CSCI score of 0.795 as a threshold for identifying sites with potentially degraded biological condition that may be considered as candidates for a Stressor/Source Identification project.

[14] The Biological Integrity Assessment Implementation Plan has been combined with the Biostimulatory Substances Amendment project. The State Water Board is proposing to adopt a statewide water quality objective for biostimulatory substances (e.g., nitrate) along with a program of implementation. A draft policy document for public review is anticipated in late 2019.



Source: http://www.dfg.ca.gov/abl/Reference/California/CA_digital_ref_familylevel_home.asp

Figure 2.1. Examples of benthic macroinvertebrates.

<u>Benthic Algae</u>

Similar to BMI's, the abundance and type of benthic algae species living on a streambed can indicate stream health. When evaluated with the CSCI, biological indices based on benthic algae can provide a more complete picture of the streams biological condition because algae respond more directly to nutrients and water chemistry. In contrast, BMIs are more responsive to physical habitat. Figure 2.2 shows examples of benthic algae common in Bay Area streams.

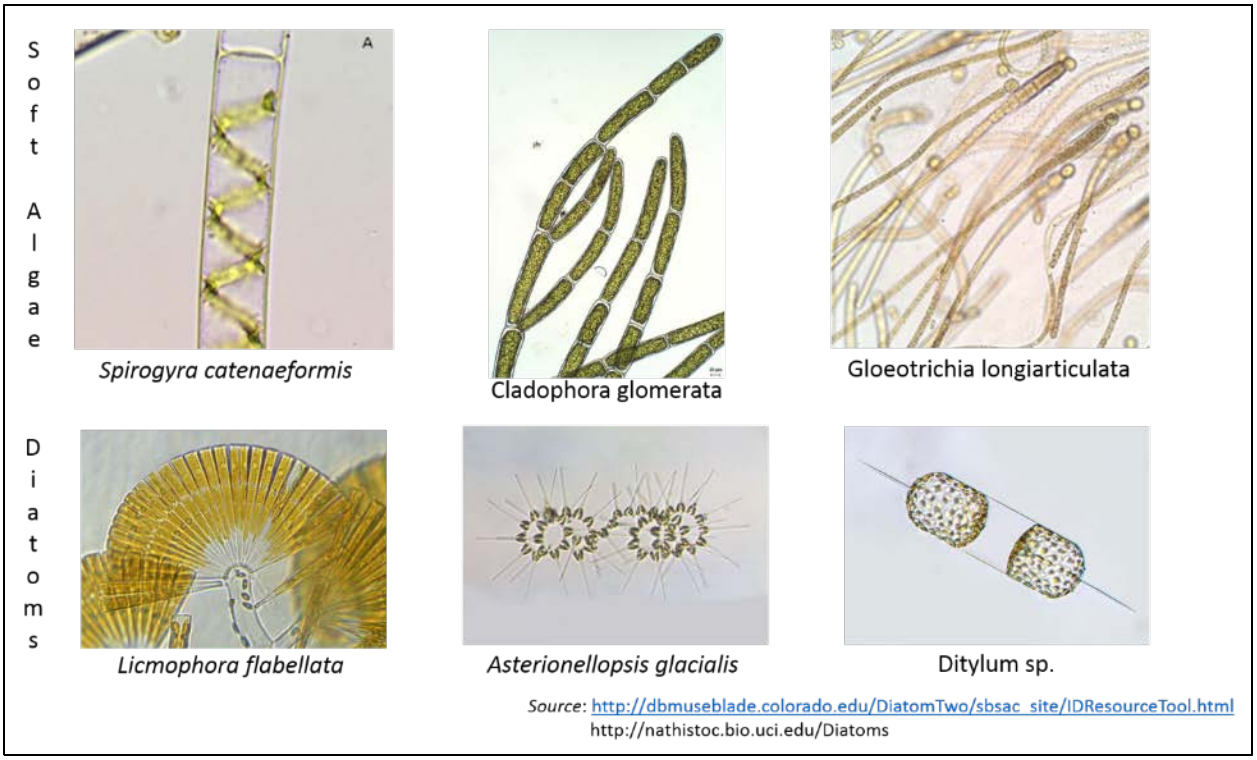


Figure 2.2. Examples of soft algae and diatoms.

The State Water Board and SCCWRP recently developed the draft Algae Stream Condition Index (ASCI) which uses benthic algae data as a measure of biological condition for streams in California (Theroux et al. in prep.). The ASCI is a non-predictive[15] scoring tool that consists of three multimetric indices (MMI) comprised of single-assemblage metrics associated with either diatoms or soft algae, or combinations of metrics representing both assemblages (i.e, "hybrid"). The individual metrics associated with hybrid MMI include five of the six metrics used for the diatom MMI. The soft algae metrics used in the hybrid MMI are different than metrics used in the soft algae MMI.

The ASCI is very similar to the algae Indices of Biological Integrity (IBIs) developed in Southern California (Fetscher et al. 2014), with the exception that metric development and testing was conducted using data collected throughout California. Analysis of the three ASCI tools (i.e., diatom, soft algae, hybrid) conducted by SCCWRP suggests that the hybrid ASCI index is the most responsive algae index, especially for nutrient stressor gradients (Theroux et al. in prep.). Additional study is needed however, to determine the best approach to apply the ASCI tools to evaluate bioassessment data. For example, it is not clear if the ASCI should be used as a second line of evidence to understand CSCI scoring results, or if it would be more effective as an independent indicator to evaluate different types of stressors (e.g., nutrients) to which BMIs

[15] Predictive indices (e.g., CSCI) utilize environmental variables that characterize immutable natural gradients as predictors for biological conditions. A predictive O/E and MMI algae model was developed and tested, but ultimately not recommended due to low precision and accuracy.

are not very responsive. The ASCI is currently under review by the Biostimulatory-Biointegrity Policy Science Advisory Panel and the State Water Board.

The algae data collected in San Mateo County during 2018 were evaluated using the diatom ASCI, soft algae ASCI, and hybrid ASCI. ASCI scores were generated using the beta version reporting module developed by SCCWRP. These scores are considered provisional until the ASCI has been fully evaluated and finalized.

Physical Habitat Indicators

The condition of physical habitat is a major contributor to stream ecosystem health. Physical habitat components such as streambed substrate, channel morphology, microhabitat complexity, in-stream cover-type complexity, and riparian vegetation cover contribute to the overall physical and biological integrity of a stream. The physical characteristics of a stream reach are affected by both natural factors (e.g., climate, slope, geology) and human disturbance (e.g., channelization, development, stream crossings, hydromodification).

Physical habitat conditions are generally evaluated using endpoint variables, or metrics, which are calculated using reach-scale averages of transect-based measurements and observations. The State Water Board has developed a SWAMP Bioassessment Reporting Module (SWAMP RM), a custom Microsoft Access™ application, that produces approximately 170 different metrics that are based on physical habitat measurements collected using both EPA's Environmental Monitoring and Assessment Program (EMAP) for freshwater wadeable streams (Kaufmann et al. 1999) and the SWAMP "Full" habitat protocol (Ode et al 2007) that was implemented by SMCWPPP at bioassessment stations. The metrics are classified into five thematic groups representing different physical attributes: substrate, riparian vegetation (including structure and shading), flow habitat variability, in-channel cover, and channel morphology.

The State Water Board recently developed the Index of Physical Habitat Integrity (IPI) as an overall measure of physical habitat condition. Similar to the CSCI, the IPI is calculated using a combination of physical habitat data collected in the field and environmental data generated in GIS following the methods described in Rehn et al. (2018). The IPI is based on five of the metrics generated by the SWAMP RM. The metrics were selected for their ability to discriminate between reference and stressed sites and provide unbiased representation of waterbodies across the different ecoregions of California. Scoring for these metrics were then calibrated using environmental variables that were associated with drainage areas for each sampling location.

Biological and Physical Habitat Condition Thresholds

Existing thresholds for CSCI scores (Mazor 2015) and ASCI scores (Mazor et al. in review) were used to evaluate the BMI and algae data collected in San Mateo County and analyzed in this report (Table 2.1). Provisional thresholds for IPI scores (Rehn et al 2018) were used to evaluate physical habitat conditions. The thresholds for all three indices were based on the distribution of scores for data collected at reference calibration sites located throughout California. Four condition categories are defined by these thresholds: "likely intact" (greater than 30th percentile of reference site scores); "possibly intact" (between the 10th and the 30th percentiles); "likely altered" (between the 1st and 10th percentiles); and "very likely altered" (less than the 1st percentile).

A CSCI score below 0.795 is referenced in the MRP as a threshold indicating a potentially degraded biological community, and thus should be considered for a SSID Project. The MRP threshold is the division between "possibly intact" and "likely altered" condition category described in Mazor (2015). Further investigation is needed to evaluate the applicability of this threshold to sites in highly urban watersheds and/or modified channels that are frequent throughout the SMCWPPP study area.

Table 2.1. Condition categories used to evaluate CSCI, ASCI, and IPI scores.

Biological Indicator	Tool	Likely Intact	Possibly Intact	Likely Altered	Very Likely Altered
BMI	CSCI	≥ 0.92	≥ 0.79 to < 0.92	≥ 0.63 to < 0.79	< 0.63
Diatoms	ASCI	≥ 0.92	≥ 0.80 to < 0.92	≥ 0.63 to < 0.80	< 0.63
Soft Algae		≥ 0.93	≥ 0.82 to < 0.93	≥ 0.68 to < 0.82	< 0.68
Hybrid		≥ 0.93	≥ 0.83 to < 0.93	≥ 0.70 to < 0.83	< 0.70
Physical Habitat	IPI	≥ 0.94	≥ 0.84 to < 0.94	≥ 0.71 to < 0.83	< 0.70

Stressor Variables

Physical habitat, landscape characteristics, general water quality, and water chemistry data collected during the bioassessment surveys were compiled and evaluated as potential stressor variables affecting biological condition.

Physical habitat stressor variables include 11 of the metrics developed by the SWAMP RM (described above) that were selected based on their ability to discriminate between reference and stressed sites and also showed little bias among ecoregions (Andy Rehn, personal communication, 2017) (Table 2.2). Additional physical habitat variables include the reachwide qualitative assessment (PHAB) that consists of three separate attributes: channel alteration, epifaunal substrate, and sediment deposition. Each attribute is individually scored on a scale of 0 to 20, with a score of 20 representing good condition. The total PHAB score is the sum of three individual attribute scores with a score of 60 representing the highest possible score.

Table 2.2. Physical habitat metrics used to assess physical habitat data collected at bioassessment sites in WY 2018. The five metrics used to calculate IPI scores are also shown.

Type	Variable Name	Variables used for IPI Score
Channel Morphology	Evenness of Flow Habitat Types	x
	Percent Fast Water of Reach	
Habitat Complexity and Cover	Mean Filamentous Algae Cover	
	Natural Shelter cover - SWAMP	
	Shannon Diversity (H) of Aquatic Habitat Types	x
	Riparian Cover Sum of Three Layers	x
Human Disturbance	Combined Riparian Human Disturbance Index - SWAMP	
Substrate Size and Composition	Evenness of Natural Substrate Types	
	Percent Gravel - coarse	
	Percent Substrate Smaller than Sand (<2 mm)	x
	Shannon Diversity (H) of Natural Substrate Types	x

Landscape variables were generated in GIS using three different scales of drainage area upstream of each sampling location: 1 km, 5 km, and entire watershed. Land use and transportation data layers were overlayed with the drainage areas to calculate landscape variables, including percent urban area, percent impervious area, total number of road crossings, and road density.

Water quality stressor variables include the general parameters measured in the field with sondes (i.e., dissolved oxygen, pH, temperature and specific conductivity), free chlorine and total chlorine residual, and water chemistry analyzed at laboratories (nutrients and anions). Additional water quality variables included chlorophyll a and ash free dry mass, both measured from filtration of the benthic algae composite samples.

Some of the water quality stressor variables used in the analysis were calculated or converted from other analytes or units of measurement:

- Conversion of measured total ammonia to the more toxic form of unionized ammonia was calculated to compare with the 0.025 mg/L annual median standard provided in the San Francisco Basin Water Quality Control Plan (Basin Plan) (SFRWQCB 2017). The conversion was based on a formula provided by the American Fisheries Society (AFS; https://fisheries.org/wp-content/uploads/2016/03/Copy-of-pub_ammonia_fwc.xls). The calculation requires total ammonia and field-measured values of pH, temperature, and specific conductance.
- Total nitrogen concentration was calculated by summing nitrate, nitrite, and Total Kjeldahl Nitrogen concentrations.
- The volumetric concentrations (mass/volume) for ash free dry mass and chlorophyll a (as measured by the laboratory) were converted to an area concentration (mass/area). Calculations required using both algae sampling grab size and composite volume.

Another potential stressor is climate. During the first five years of probabilistic sampling (WY 2012 – WY 2016), average precipitation was lower than average. Drought conditions changed with an above average wet season in WY 2017, followed by average season in WY 2018. Comparison of sampling results from recent wet years will provide useful information to evaluate the impacts of drought on biological integrity of the streams.

Stressor Thresholds

In compliance with Provision C.8.h.iii.(4), water chemistry data collected at the bioassessment sites during WY 2018 were compared to stressor thresholds and applicable water quality standards (Table 2.3). Thresholds for pH, specific conductance, dissolved oxygen (DO), and temperature (for waters with COLD Beneficial Use only) are listed in Provision C.8.d.iv of the MRP. With the exception of temperature and specific conductance, these conform to Water Quality Objectives (WQOs) in the Basin Plan (SFRWQCB 2017). Of the eleven nutrients analyzed synoptically with bioassessments, WQOs only exist for three: ammonia (unionized form), and chloride and nitrate (for waters with MUN Beneficial Use only). See Table 1.4 for a list designated Beneficial Uses of creeks monitored in WY 2018. Pescadero Creek, Pilarcitos Creek and San Pedro Creeks are the only creeks sampled in WY 2018 with MUN designated.

Table 2.3. Thresholds for nutrient and general water quality variables.

	Units	Threshold	Direction	Source
Nutrients and Ions				
Nitrate as N [a]	mg/L	10	Increase	Basin Plan
Un-ionized Ammonia [b]	mg/L	0.025	Increase	Basin Plan
Chloride [a]	mg/L	250	Increase	Basin Plan
General Water Quality				
Oxygen, Dissolved	mg/L	5.0 or 7.0	Decrease	Basin Plan
pH		6.5 and 8.5		Basin Plan
Temperature, instantaneous maximum [c]	°C	24	Increase	MRP
Specific Conductance [c]	µS/cm	2000	Increase	MRP

[a] Nitrate and chloride WQOs only apply to waters with MUN designated Beneficial Uses.
[b] This threshold is an annual median value and is not typically applied to individual samples.
[c] The MRP thresholds (or triggers) for temperature and specific conductance apply when 20 percent of instantaneous results are in exceedance. Application to individual samples is provisional.

Stressor Assessment

The association of stressors with biological indicator scores was evaluated using simple regression models. Linear regressions were run between variables within each of the stressor data types (e.g., landscape, physical habitat and water chemistry) and biological conditions indicators (i.e., CSCI and ASCI scores). Scatter plots showing trend lines are presented for some of the variables that had the greatest positive or negative correlation. However, the correlations were not expected to be very strong or significant due to the small WY 2018 sample size (n=10). More sophisticated statistical analyses using non-parametric measures of correlation (e.g., random forest models) are applied to the regional WY 2012 – WY 2016 dataset in the RMC 5-Year Report, summarized in Section 7.1 and included as Attachment 2.

2.3 Results and Discussion

The section below summarizes results from bioassessment sampling conducted during WY 2018. Conclusions and recommendations for this section are presented in Section 7.0.

A comprehensive analysis of bioassessment data collected by SMCWPPP over a five-year period is presented in the RMC Five-Year Bioassessment Report (5-Year Report) (BASMAA 2019). This BASMAA-funded project evaluated bioassessment data collected at all RMC (n=312) and Water Board (n=45) probabilistic monitoring sites sampled between WY 2012 and WY 2016. The data were evaluated to assess overall biological condition of streams within the RMC, as well as the extent and influence of stressor data on biological condition scores. In addition, the 5-Year Report evaluated the RMC Sample Frame and provided potential recommendations for revising the monitoring design in the future. Additional analysis of the full SMCWPPP MRP bioassessment dataset will be conducted for the Integrated Monitoring Report which will be developed following WY 2019 and submitted by March 31, 2020 (the fifth year of the Permit term) in lieu of an annual UCMR.

2.3.1 Site Evaluations

During WY 2018, SMCWPPP conducted site evaluations at a total of 23 potential probabilistic sites in San Mateo County that were drawn from the Sample Frame. Of these sites, ten were sampled in WY 2018 (rejection rate of 57%). Seven of the evaluated sites were rejected due to access issues and three sites were rejected due to low flow conditions. Two of the sampled sites were classified as non-urban land use and the remaining sites were classified as urban. Two non-urban and four urban sites were located in coastal watersheds draining into the Pacific Ocean, including two sites in Pilarcitos Creek and two sites in San Pedro Creek. The remaining four sites were located in urban watersheds draining into the San Francisco Bay. Two of the urban sites were located in San Francisquito Creek watershed. Land use classification, sampling location, and date for each sampled site are listed are Table 2.4. Sites are mapped in Figure 1.1.

Table 2.4. SMCWPPP bioassessment sampling locations and dates in San Mateo County in WY 2018.

Station Code	Drainage	Watershed	Creek	Land Use	Sample Date	Latitude	Longitude
202R00584	Ocean	Pilarcitos Creek	Pilarcitos Creek	NU	5/15/2018	37.49547	-122.38512
202R00614		Pescadero Creek	Pescadero Cr	NU	5/14/2018	37.27410	-122.28860
202R03404		San Pedro Creek	San Pedro Cr	U	5/17/2018	37.58203	-122.48719
202R03656		Pilarcitos Creek	Pilarcitos Creek	U	5/15/2018	37.46781	-122.42269
202R03880		San Gregorio Cr	La Honda Creek	U	5/22/2018	37.38759	-122.27219
202R03916		San Pedro Creek	San Pedro Cr	U	5/17/2018	37.59144	-122.50333
204R03508	Bayside	Mills Creek	Mills Creek	U	5/16/2018	37.59105	-122.37406
204R03528		San Mateo Creek	San Mateo Cr	U	5/16/2018	37.54808	-122.34661
205R03624		San Francisquito Cr	Bear Creek	U	5/21/2018	37.41883	-122.26498
205R03864		San Francisquito Cr	Hamms Gulch	U	5/22/2018	37.36498	-122.22906

NU = non-urban, U = urban

Since WY 2012, a total of 80 probabilistic sites were sampled by SMCWPPP (n=70) and SWAMP (n=10) in San Mateo County. During the seven-year sampling period, SMCWPPP sampled 57 urban sites and 13 non-urban sites; SWAMP sampled 10 non-urban sites.

2.3.2 Biological Condition Assessment

A total of 112 unique BMI taxa were identified in samples collected at the ten bioassessment sites in San Mateo County during WY 2018. A total of 139 benthic algae taxa were identified in samples collected at the sites, including 119 diatom and 20 soft algae taxa. The total number of unique BMI, diatom, and soft algae taxa identified at each bioassessment location is presented in Table 2.4. BMIs and diatoms were relatively well represented across all sites, with BMIs ranging from 14 to 54 taxa, and diatoms ranging from 26 to 48 taxa. Soft algae taxa were less common across sites, ranging from 1 to 11 taxa, with five sites having 3 or fewer taxa.

Low diversity of soft algae at San Mateo County sites has been frequently observed in prior years, particularly in the upper reaches of coastal creeks with dense riparian canopies. Factors causing low algal diversity are unknown and may include: sand-dominated substrate, low flow conditions related to prolonged drought, dense canopy cover limiting exposure to sunlight, and competition with diatoms.

Table 2.5. The total number of unique BMI, diatom, and soft algae taxa identified in samples collected at 10 bioassessment sites in San Mateo County during WY 2018.

RMC Station	Creek Name	Land Use	BMI	Diatoms	Soft Algae
202R00584	Pilarcitos Creek	NU	45	41	3
202R00614	Pescadero Creek	NU	54	38	11
202R03404	San Pedro Creek	U	18	47	5
202R03656	Pilarcitos Creek	U	26	47	2
202R03880	La Honda Creek	U	42	32	3
202R03916	San Pedro Creek	U	21	45	2
204R03508	Mills Creek	U	14	26	5
204R03528	San Mateo Creek	U	24	48	8
205R03624	Bear Creek	U	51	33	4
205R03864	Hamms Gulch	U	49	32	1

NU = non-urban, U = urban

The total number of BMI taxa (i.e., BMI richness) was slightly positively correlated with site elevation (r^2=0.27, p-value = 0.124) (Figure 2.3).[16] In contrast, total taxa for diatoms generally decreased with increasing site elevation (r^2=0.24, p-value = 0.146). BMI richness was not correlated with diatom or soft algae richness across the 10 bioassessment sites sampled in WY 2018. Similarly, diatom richness did not appear to have any correlation with soft algae richness.

[16] R-squared represents the amount of variance in the dependent variable. The higher the R-square the better the model. The p-value represents the statistical significance of the result. A small p-value (≤ 0.05) indicates strong evidence; a large p-value (> 0.05) indicates weak evidence.

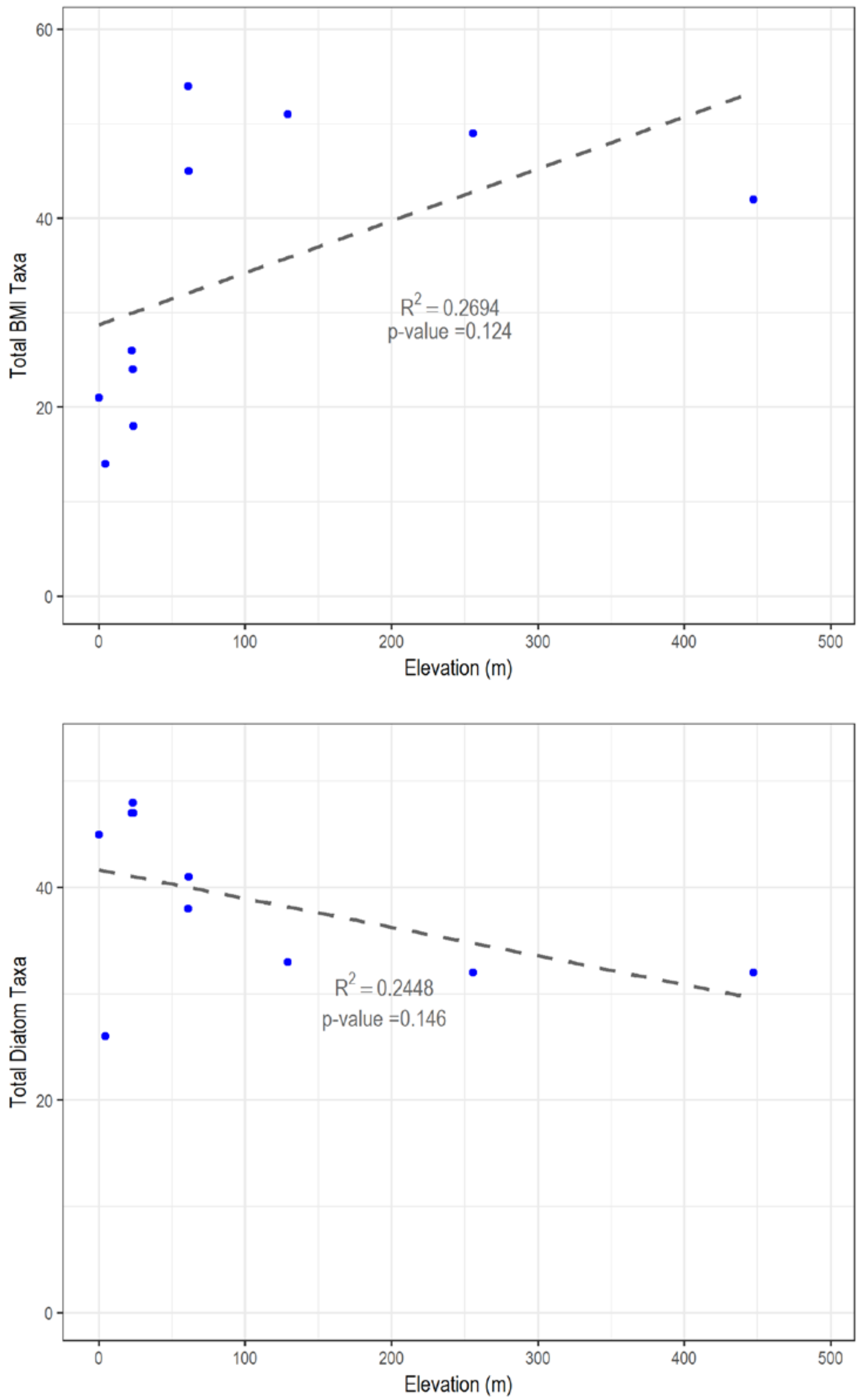


Figure 2.3. Total BMI (top) and soft algae (bottom) taxa compared to elevation of bioassessment sites, SMCWPPP, WY 2018.

Biological condition, as represented by CSCI and ASCI (diatom, soft algae, and hybrid) scores, for the 10 probabilistic sites sampled by SMCWPPP in WY 2018 are listed in Table 2.6 and mapped in Figure 2.6. Scores in the two higher condition categories (i.e., above the 10th percentile of reference sites) for each indicator are highlighted and bold.

Table 2.6. Biological condition scores, presented as CSCI and ASCI (diatom, soft algae and hybrid) for 10 probabilistic sites sampled in San Mateo during WY 2018. Site characteristics related to percent impervious watershed area, channel modification and flow condition are also presented. Bold highlighted values indicate scores in the two higher condition categories.

Station Code	Creek	Land Use	Impervious Watershed Area (%)	Modified Channel [1]	CSCI Score	ASCI Score		
						Diatom	Soft Algae	Hybrid
202R00584	Pilarcitos Creek	NU	1%	N	**0.86**	**0.92**	0.79	**0.88**
202R00614	Pescadero Creek	NU	1%	N	**1.17**	**1.17**	**0.84**	**0.98**
202R03404	San Pedro Creek	U	13%	N	0.65	**0.86**	**0.98**	**0.89**
202R03656	Pilarcitos Creek	U	2%	N	0.71	**0.90**	NS	0.80
202R03880	La Honda Creek	U	5%	N	**0.99**	**0.89**	**0.91**	**0.94**
202R03916	San Pedro Creek	U	15%	N	0.68	**0.87**	0.79	0.82
204R03508	Mills Creek	U	47%	Y	0.35	**0.81**	0.71	0.82
204R03528	San Mateo Creek	U	7%	N	0.60	**1.05**	0.71	**1.00**
205R03624	Bear Creek	U	3%	N	**1.2**	**0.82**	**1.01**	**0.89**
205R03864	Hamms Gulch	U	1%	N	**1.14**	0.78	NS	**0.90**

NS - No score was calculated due to inadequate number of soft algal taxa.
NU = non-urban, U = urban
[1] Highly modified channel is defined as having armored bed and banks (e.g., concrete, gabion, rip rap) for majority of the reach or characterized as highly channelized earthen levee.

CSCI Scores

The CSCI scores ranged from 0.35 to 1.2 across the ten bioassessment sites sampled in WY 2018 (Table 2.6). Five of the ten (50%) sites had CSCI scores in the two higher condition categories: “possibly intact” and “likely intact”. These combined classifications are above the MRP trigger threshold value of 0.795. Three of these sites were located in protected open space or County Park land and two sites were in private property near the urban boundary line.

Three sites had CSCI scores in the “likely altered” conditions category (0.63 – 0.79). These sites are located in urban reaches of San Pedro Creek (City of Pacifica) and Pilarcitos Creek (City of Half Moon Bay. Two sites had CSCI scores in the “very likely altered” category (< 0.63). The site with the lowest CSCI score (0.35), was in a highly developed reach of Mills Creek (City of Burlingame).

Sites with CSCI scores below 0.795 will be considered as candidates for SSID projects.

ASCI Scores

The benthic algae taxa identified in the ten samples collected in San Mateo County were used to calculate scores for the provisional statewide ASCI. Scores for three ASCI indices (diatoms, soft algae and hybrid) are shown in Table 2.6. In general, ASCI scores across the three indices were relatively high (> 0.7) across the ten bioassessment sites.

- **Diatoms.** Nine of the ten bioassessment sites had diatom ASCI scores that were classified as “possibly intact” or “likely intact” condition. The higher scoring sites occurred over a wide gradient of urbanization, ranging from 1% to 47% impervious area (Table 2.6).

- **Soft Algae**. Four of the ten bioassessment sites had soft algae ASCI scores that were classified as “possibly intact” or “likely intact” condition. The higher scoring sites occurred over a wide gradient of urbanization, ranging from 1% to 13% impervious area. Soft algae ASCI scores were not calculated for two sites; both sites had two or fewer soft algae taxa identified in the samples (Table 2.6).

- **Hybrid**. Seven of the ten bioassessment sites had hybrid ASCI scores that were classified as “possibly intact” or “likely intact” condition. The higher scoring sites occurred primarily in drainages with low ubanization, ranging from 1% to 7% impervious area, with the exception of site 202R03404 in San Pedro Creek (13%). Five of the seven sites also received CSCI scores that were in two higher condition categories (Table 2.6).

CSCI scores were poorly correlated with ASCI scores. A comparison of CSCI and hybrid ASCI scores is shown in Figure 2.4.

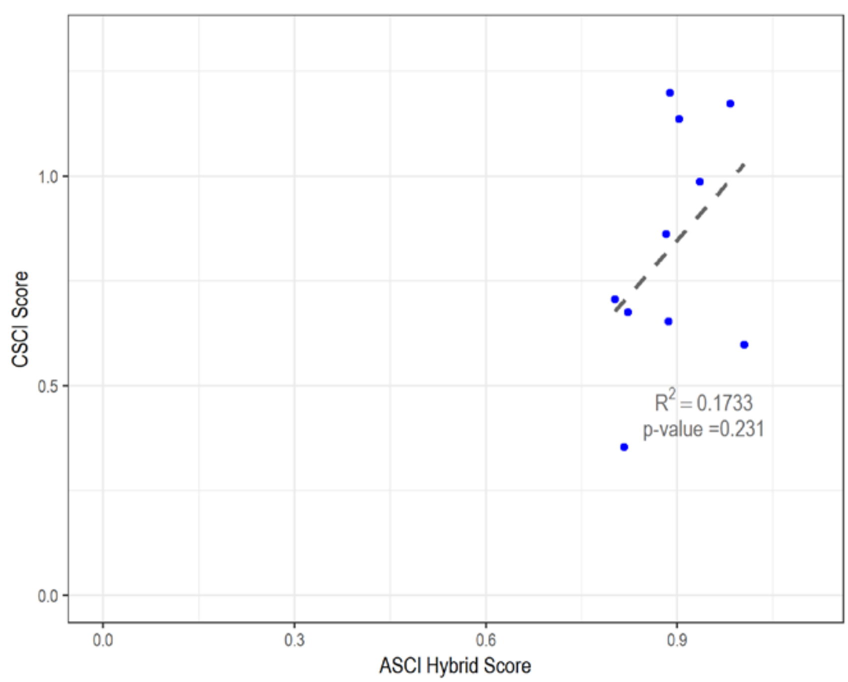


Figure 2.4. CSCI Scores compared to hybrid ASCI Scores for 10 bioassessment sites sampled in San Mateo County in WY 2018.

A statewide bioassessment data analysis evaluated the CSCI and the three ASCI indices and concluded that the hybrid ASCI index was the most responsive index[17], especially for nutrient stressor gradients (Theroux et al. in prep.). Additional guidance is needed however, to determine the best application of the ASCI tool in evaluating bioassessment data. For example, it is not clear if one or more of the ASCI indices should be used to assess biological condition. Furthermore, it is not clear if ASCI should be used as a second line of evidence to the CSCI scoring results, or if it would be more effective as an independent indicator to evaluate different types of stressors (e.g., nutrients).

IPI Scores

Physical habitat conditions, as represented by IPI scores, are listed in Table 2.7. The qualitative habitat (PHAB) scores, including individual scores for channelization, epifaunal substrate and sedimentation attributes, and total PHAB (sum of the three attributes scores) are also presented in the table. Biological condition scores for CSCI and the hybrid ASCI are included in the table for comparison. The two higher condition categories for all three indices (i.e., above the 10th percentile of reference sites) are shown in shaded cells with bold text.

Table 2.7. IPI scores for ten probabilistic sites sampled by SMCWPPP in WY 2018. Qualitative PHAB scores are also listed. CSCI and hybrid ASCI scores are provided for comparison.

Station Code	Creek	CSCI Score	ASCI Hybrid	IPI Score	Channel Alteration	Epifaunal Substrate	Sediment Deposition	Total PHAB Score
202R00584	Pilarcitos Creek	**0.86**	**0.88**	0.8	12	15	10	37
202R00614	Pescadero Creek	**1.17**	**0.98**	**1.04**	14	13	13	40
202R03404	San Pedro Creek	0.65	**0.89**	**1**	15	16	6	37
202R03656	Pilarcitos Creek	0.71	0.80	0.7	14	4	3	21
202R03880	La Honda Creek	**0.99**	**0.94**	**1.15**	18	17	9	44
202R03916	San Pedro Creek	0.68	0.82	**1.06**	17	9	10	36
204R03508	Mills Creek	0.35	0.82	0.62	6	7	14	27
204R03528	San Mateo Creek	0.60	**1.00**	**0.92**	16	14	7	37
205R03624	Bear Creek	**1.20**	**0.89**	**1.21**	11	15	12	38
205R03864	Hamms Gulch	**1.14**	**0.90**	**1.16**	20	15	11	46

IPI scores, composed of metrics that are primarily based on physical habitat measurements, were positively correlated with the qualitative habitat assessment PHAB scores ($r^2 = 0.69$, p-value = 0.003) (Figure 2.5). IPI scores were also positively correlated with CSCI scores, and slightly less so with hybrid ASCI scores. ($r^2 = 0.57$, p value = 0.125 and $r^2 = 0.2$, p value = 0.193, respectively) (Figure 2.5).

Individual physical habitat variables and metrics are evaluated as stressors in the next section of the report.

[17] For the remainder of this report, the hybrid ASCI will be used to evaluate stressor association with biological condition.

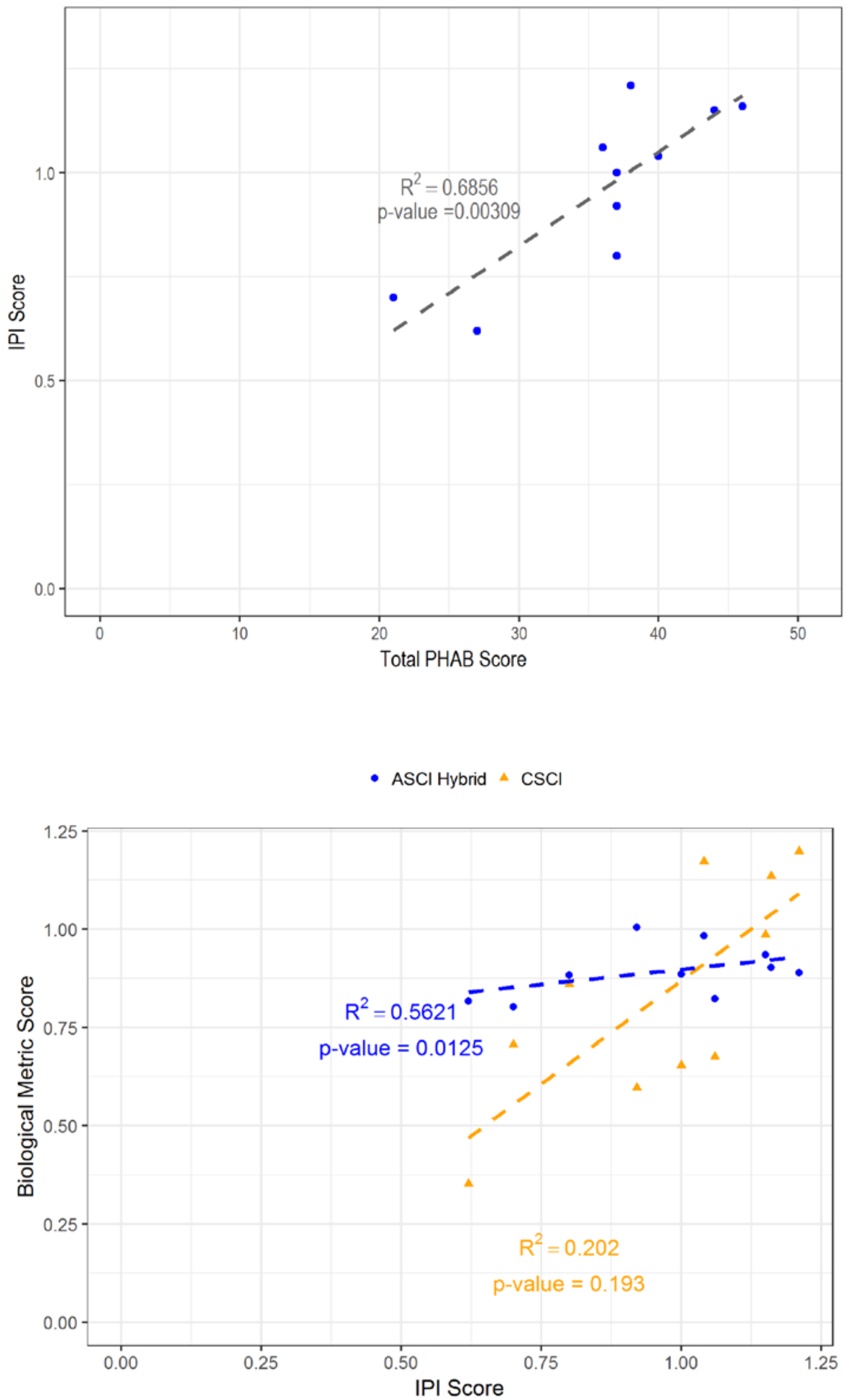


Figure 2.5. Total PHAB scores compared with IPI scores (top) and CSCI and hybrid ASCI scores (bottom) plotted with IPI scores for ten bioassessment sites sampled in WY 2018.

Overall Condition

The condition categories for two of the biological indicators (CSCI, hybrid ASCI) and the IPI, as defined in Table 2.1, are mapped in Figure 2.6. There were four sites with scores in the two higher condition categories for all three indices (green and yellow symbols in Figure 2.6). Two of the high-scoring sites were located in Mid-Peninsula Open Space District land, including La Honda Creek Preserve (site 202R03880) and Hamms Gulch at Windy Hill Preserve (site 205R03864). The third site was located in Pescadero Creek County Park (site 202R00614). The fourth site was on Bear Creek, near the urban boundary of the Town of Woodside (site 205R03624). All four sites were relatively undeveloped (less than < 5% impervious area).

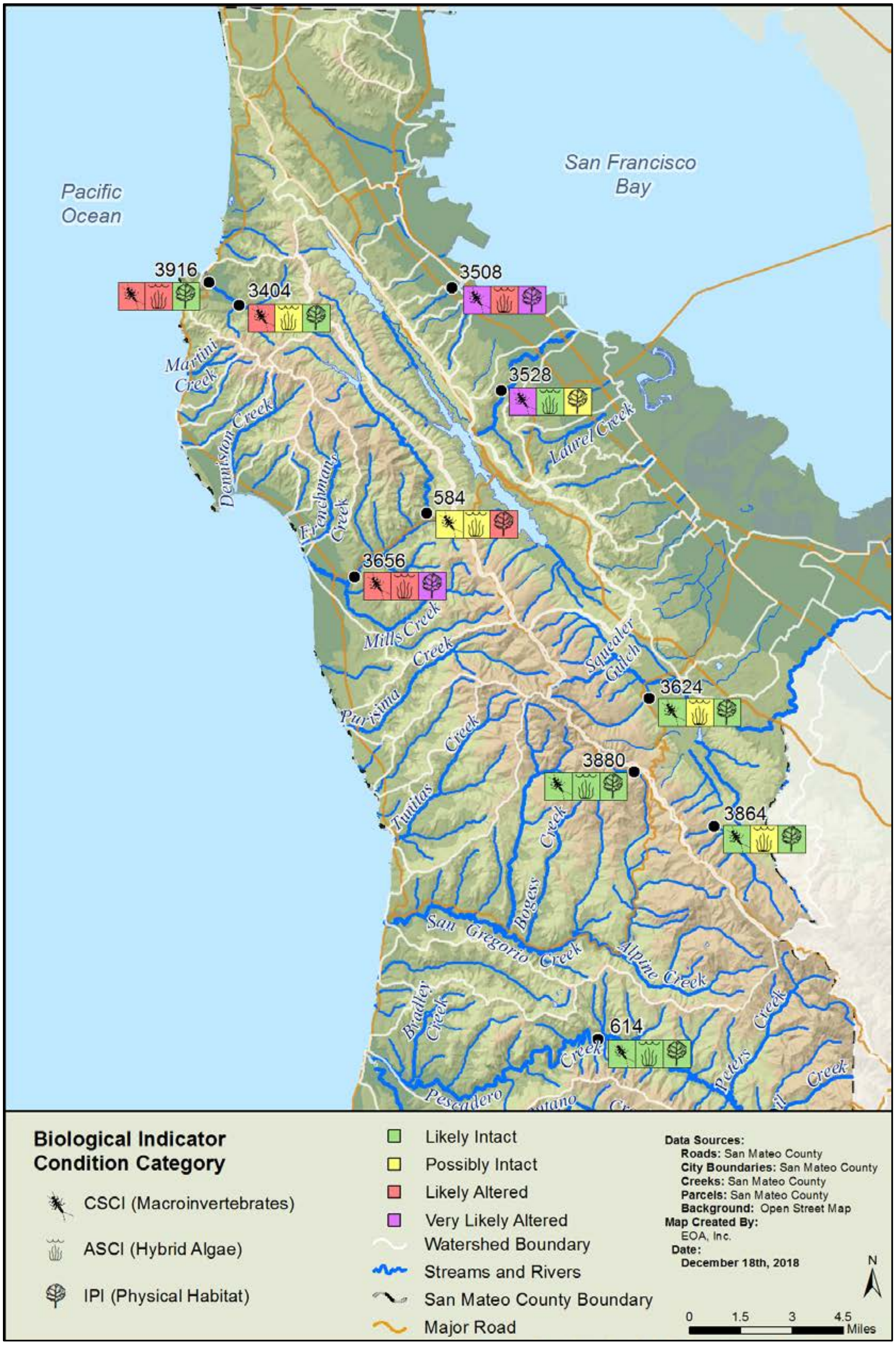


Figure 2.6. Condition category as represented by CSCI, hybrid ASCI and IPI Scores for ten probabilistic sites sampled in San Mateo County in WY 2018.

2.3.3 Stressor Assessment

This section summarizes results for stressor data collected at 10 bioassessment sites during WY 2018. Stressors were evaluated using simple linear regressions between variables within each of the stressor data types (e.g., landscape, physical habitat and water chemistry) and biological conditions indicators (i.e., CSCI and ASCI scores). Scatter plots showing trend lines are presented for some of the variables that had the greatest positive or negative correlation. However, due to the small number of samples, associations with biological condition are not expected to be very strong.

General Water Chemistry

General water quality measurements sampled at the ten bioassessment sites in WY 2018 are listed in Table 2.8. None of the water quality measurements exceeded water quality objectives or MRP trigger thresholds. Nor were any of the water quality measurements well correlated with CSCI or hybrid ASCI scores.

Table 2.8. General water quality measurements for ten probabilistic sites in San Mateo County sampled in WY 2018.

Station Code	Creek Name	Temp (C)	DO (mg/L)	pH	Specific Conductance (uS/cm)
202R00584	Pilarcitos Creek	13.3	9.5	7.5	321
202R00614	Pescadero Creek	13.7	10.5	8.0	644
202R03404	San Pedro Creek	13.5	10.0	7.9	459
202R03656	Pilarcitos Creek	12.8	10.3	7.7	379
202R03880	La Honda Creek	10.7	12.5	8.2	497
202R03916	San Pedro Creek	14.1	10.1	8.1	456
204R03508	Mills Creek	13.2	10.0	7.9	664
204R03528	San Mateo Creek	13.2	10.7	7.8	244
205R03624	Bear Creek	12.7	10.5	8.2	562
205R03864	Hamms Gulch	10.9	10.4	7.8	694

Landscape Variables

Landscape variables associated with the drainage area for each bioassessment site sampled in WY 2018 are presented in Table 2.9. Landscape variables include: percent urban area, percent impervious area, total number of road crossings, and road density (road length/watershed area). The total drainage area and CSCI scores are presented for comparison. Based on the simple regression models, the strongest relationships between CSCI scores and landscape variables were for impervious area ($r^2 = 0.55$, p value < 0.015) and road density ($r^2 = 0.47$, p value < 0.03) (Figure 2.7). The same two landscape variables were poorly correlated with the ASCI scores (not shown)

Table 2.9. Landscape variables for watershed areas of the 10 bioassessment sites sampled in San Mateo County during WY 2018.

Station Code	Creek Name	CSCI Score	Drainage Area (km2)	Percent Urban	Percent Impervious	Road Crossings Watershed	Road Density (km/km2)
202R00584	Pilarcitos Creek	0.86	23	0%	1%	1	0.4
202R00614	Pescadero Creek	1.17	107	0%	1%	45	1.4
202R03404	San Pedro Creek	0.65	13	23%	13%	19	2.8
202R03656	Pilarcitos Creek	0.71	46	1%	2%	17	0.7
202R03880	La Honda Creek	0.99	3	10%	4%	0	2.4
202R03916	San Pedro Creek	0.68	20	26%	15%	24	3.5
204R03508	Mills Creek	0.35	3	91%	47%	4	11.8
204R03528	San Mateo Creek	0.60	81	10%	7%	38	2.4
205R03624	Bear Creek	1.20	7	6%	3%	1	1.1
205R03864	Hamms Gulch	1.14	1	0%	1%	0	0.9

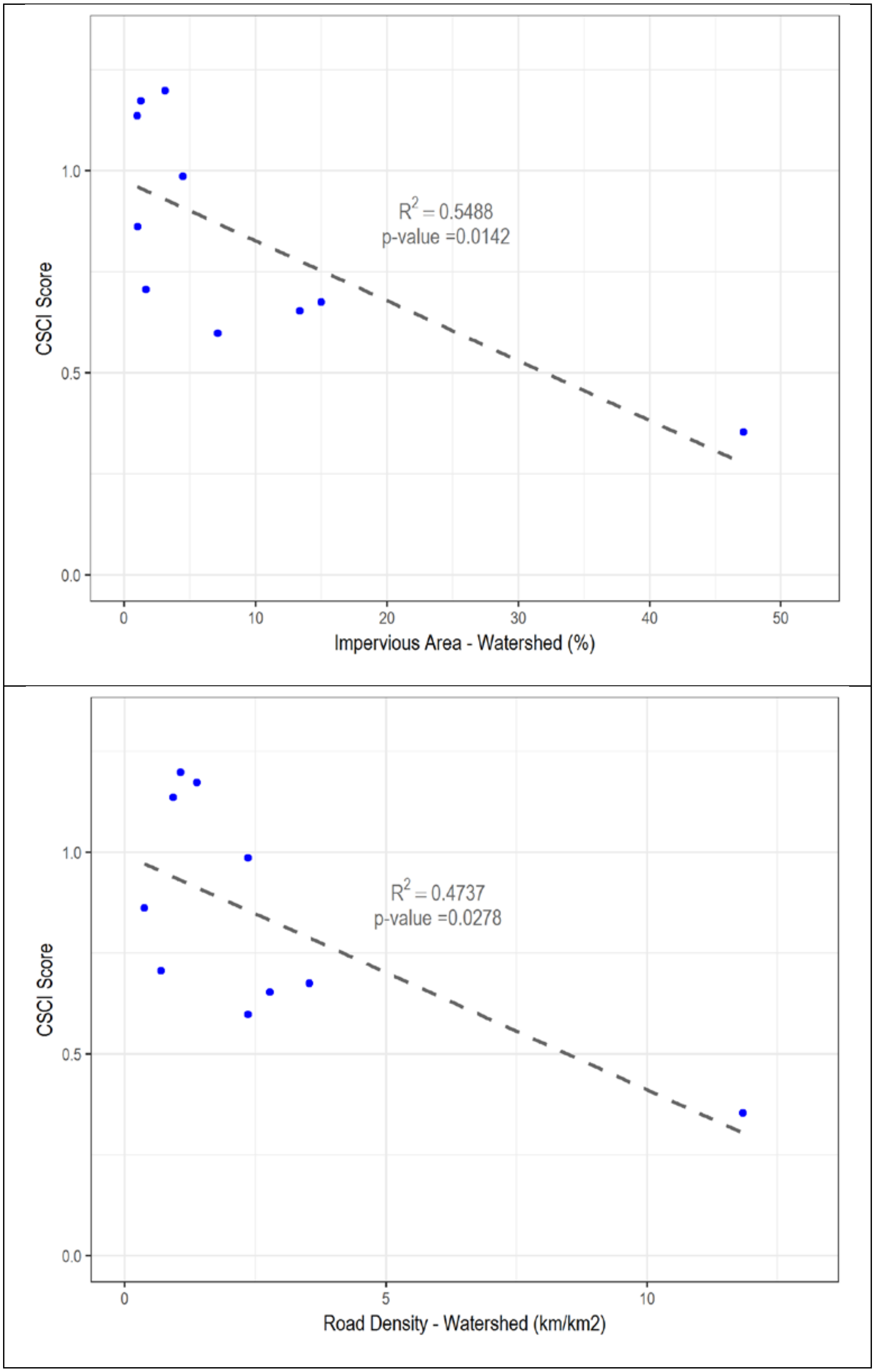


Figure 2.7. CSCI scores compared to landscape variables (percent impervious and road density) for 10 bioassessment sites sampled in San Mateo County in WY 2018.

Physical Habitat

Scores for eleven physical habitat metrics that were generated from the physical habitat data collected at bioassessment sites in WY 2018 are listed in Table 2.10. Based on the simple regression models, the strongest relationships between CSCI scores and physical habitat were for *Evenness Flow Habitat* (r^2 = 0.52, p-value <0.02) and negatively correlated with *Mean Filamentous Algae Cover* (r^2 = 0.41, p-value < 0.05) (Figure 2.8). The same two landscape variables were less correlated with the ASCI scores (not shown).

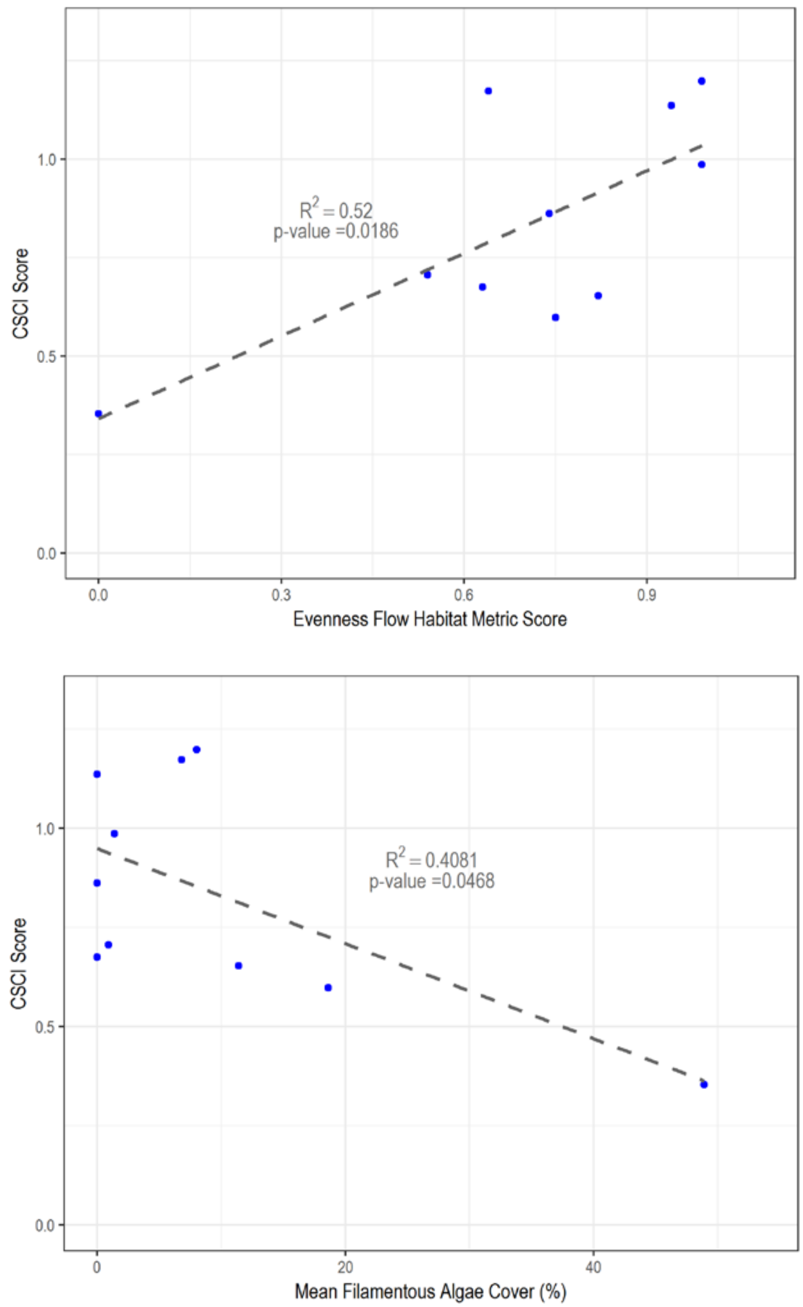


Figure 2.8. CSCI Scores compared to PHAB metric scores (Evenness Flow Habitat and Mean Filamentous Algae Cover) for 10 bioassessment sites sampled in San Mateo County in WY 2018.

Water Chemistry (Nutrients)

Nutrient and conventional analyte concentrations measured in water samples collected at ten bioassessment sites in San Mateo County during WY 2018 are listed in Table 2.11. There were no water quality objective exceedances for water chemistry parameters.

Total nitrogen concentrations ranged from 0.22 to 1.1 mg/L. Total phosphorus concentrations ranged from <0.01 to 0.12 mg/L. Neither of the nutrient parameters were correlated with CSCI or hybrid ASCI scores.

In an effort to assess whether nutrient concentrations (measured during bioassessments) are affecting indicators of biomass (i.e., chlorophyll a, ash free dry mass, percent algae cover), simple regression models were run. Neither of the biomass indicators were correlated with algae cover or nutrients for the WY 2018 dataset.

Table 2.10. Scores for 11 PHAB metrics calculated from physical habitat data collected at ten probabilistic sites in San Mateo County during WY 2018.

Station Code	CSCI Score	Channel Morphology		Habitat Complexity and Cover				Substrate Size and Composition				Human Disturbance
		Evenness of Flow Habitat Types [1]	Percent Fast Water of Reach	Shannon Diversity of Aquatic Habitat Types [1]	Natural Shelter Cover	Mean Filamentous Algae Cover	Riparian Cover Sum of 3 Layers [1]	Evenness of Natural Substrate Types	Shannon Diversity of Natural Substrate Types [1]	Percent Gravel - Coarse	Percent Substrate Smaller than Sand (<2 mm) [1]	Riparian Human Disturbance Index
202R00584	0.86	0.7	66	1.6	81	0	45	0.9	1.7	25	42	2.7
202R00614	1.17	0.6	74	1.9	21	7	105	0.9	1.6	39	19	1.7
202R03404	0.65	0.8	48	1.7	44	11	94	0.8	1.7	22	29	2.5
202R03656	0.71	0.5	78	1.5	77	1	96	0.8	1.2	17	65	3.1
202R03880	0.99	1.0	44	1.5	66	1	234	0.7	1.5	32	32	0.6
202R03916	0.68	0.6	10	1.6	26	0	102	0.8	1.5	44	32	2.5
204R03508	0.35	0.0	0	0.9	17	49	59	0.8	1.4	34	17	5.3
204R03528	0.60	0.8	67	1.8	35	19	71	0.9	1.5	30	44	2.3
205R03624	1.20	1.0	55	1.6	39	8	157	0.9	1.6	30	22	4.3
205R03864	1.14	0.9	36	1.4	29	0	145	0.9	1.7	30	27	0.0

[1] One of the five metrics used for development of the Index for Physical Habitat Integrity (IPI)

Table 2.11. Nutrient and conventional constituent concentrations in water samples collected at ten sites in San Mateo County during WY 2018. No water quality objectives were exceeded. See Table 2.1 for WQO values.

Station Code	Creek	Ammonia as N	Unionized Ammonia (as N)	Chloride	AFDM	Chlorophyll a	Nitrate as N	Nitrite as N	Total Kjeldahl Nitrogen As N	Total Nitrogen	Ortho-Phosphate as P	Phosphorus as P	Silica as SiO2	Macro Algae Cover
		mg/L	mg/L	mg/L	g/m2	mg/m2	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	%
Water Quality Objective:		*NA*	*0.025 [b]*	*250 [a]*	*NA*	*NA*	*10 [a]*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*
202R00584	Pilarcitos Creek	0.03	< 0.001	23	26	2	0.46	0.003 J	0.31	0.77	0.02	0.08	32.38	0
202R00614	Pescadero Creek	0.05	0.001	38	48	30	0.06	0.001 J	0.44	0.50	0.10	0.12	12.38	32
202R03404	San Pedro Creek	0.05	0.001	26	43	10	0.49	0.007	0.44	0.94	0.02	< 0.007	0.95	12
202R03656	Pilarcitos Creek	0.04	< 0.001	33	40	< 2.5	0.85	0.003 J	0.26	1.11	0.04	0.08	0.00	1
202R03880	La Honda Creek	0.77	0.021	22	19	12	0.09	< 0.001	0.13	0.22	0.02	0.01	1.90	0
202R03916	San Pedro Creek	0.08	0.002	28	58	9	0.50	0.006	0.35	0.86	0.03	< 0.007	40.00	2
204R03508	Mills Creek	0.04	0.001	51	38	86	0.11	0.002 J	0.4	0.51	0.05	0.03	7.62	40
204R03528	San Mateo Creek	0.07	0.001	16	33	14	0.14	0.001 J	0.35	0.49	0.01	< 0.007	2.86	8
205R03624	Bear Creek	0.03	0.001	17	64	31	0.16	< 0.001	0.35	0.51	0.09	0.10	0	3
205R03864	Hamms Gulch	0.77	0.009	33	92	< 3.0	0.10	< 0.001	0.35	0.45	0.09	0.09	0	0
Number of exceedances		NA	0	0	NA	NA	0	NA	NA	NA	NA	NA	NA	NA

NA = Not Applicable
J = The reported result is an estimate.
[a] Chloride and nitrate WQOs only apply to waters with MUN designated Beneficial Uses.
[b] This threshold is an annual median value and is not typically applied to individual samples.

3.0 Continuous Water Quality Monitoring

3.1 Introduction

During WY 2018 water temperature and general water quality were monitored in compliance with Creek Status Monitoring Provisions C.8.d.iii – iv of the MRP. Monitoring was conducted at selected sites using a targeted design based on the directed principle[18] to address the following management questions:

1. *What is the spatial and temporal variability in water quality conditions during the spring and summer season?*
2. *Do general water quality measurements indicate potential impacts to aquatic life?*

The first management question is addressed primarily through evaluation of water quality results in the context of existing aquatic life uses. Temperature and general water quality data were evaluated for potential impacts to different life stages and overall population of fish community present within monitored reaches.

The second management question is addressed primarily through the evaluation of targeted data with respect to water quality objectives and thresholds from published literature. Sites where exceedances occur may indicate potential impacts to aquatic life or other beneficial uses and are considered as candidates for future Stressor/Source Identification projects.

3.2 Study Area

In compliance with the MRP, temperature was monitored at four sites, and general water quality was monitored at two sites. The targeted monitoring design focuses on sites selected based on the presence of significant fish and wildlife resources as well as historical and/or recent indications of water quality concerns.

3.2.1 Temperature and General Water Quality

Continuous (hourly) temperature measurements were recorded from April 5 through September 25, 2018, at five locations[19] in San Pedro Creek. Continuous (15-minute) general water quality measurements (temperature, dissolved oxygen, pH, specific conductance) were recorded at two of the temperature stations during two two-week sampling events (Events 1 and 2). Sample Event 1 occurred from May 4 through May 17, 2018. Sample Event 2 occurred from August 10 through August 21, 2018. The same locations were monitored for continuous temperature and water quality as part of MRP Creek Status Monitoring during WY 2017. Temperature and general water quality monitoring stations for both years are illustrated in Figure 3.1.

San Pedro Creek, located in the City of Pacifica, was targeted for temperature and general water quality monitoring because it contains the northern-most population of naturally producing steelhead trout (*Oncorhynchus mykiss*) in San Mateo County (Titus et al. 2010). The San Pedro Creek watershed is approximately 8 square miles and encompasses the urban communities of

[18] Directed Monitoring Design Principle: A deterministic approach in which points are selected deliberately based on knowledge of their attributes of interest as related to the environmental site being monitored. This principle is also known as "judgmental," "authoritative," "targeted," or "knowledge-based."

[19] SMCWPPP typically monitors water temperature at more stations than the MRP requires to mitigate for potential equipment loss.

Linda Mar, Sun Valley and Park Pacifica. The majority of South and Middle Fork subwatersheds are located within the undeveloped and public lands of San Pedro Valley County Park; these sub-watersheds account for approximately 25% of the total watershed area.

Although degradation of physical habitat and the presence of fish barriers such as bridge culverts may threaten the steelhead population in San Pedro Creek, restoration efforts are helping to reestablish and enhance habitat. For example, in 2005 the City of Pacifica removed a fish passage and migration barrier at Capistrano Avenue Bridge and restored approximately 1,300 linear feet of channel. The City also implemented the San Pedro Creek Flood Control Project which reconstructed a meandering channel and active floodplain in the lower 3,100-feet of San Pedro Creek.

In WY 2018, SMCWPPP conducted bioassessment monitoring at two locations on San Pedro Creek: one near the mouth of creek and one just upstream of the confluence with Brooks Creek (also known as the Sanchez Fork) (Figure 3.1). CSCI scores were in the “likely altered” condition categories. In WY 2015, SCMWPPP conducted bioassessment monitoring farther up in the watershed at two locations on the Middle Fork of San Pedro Creek. CSCI scores were in the “possibly intact” and “likely intact” stream condition categories. The mouth of San Pedro Creek was also targeted for wet weather Pesticides and Toxicity monitoring in WY 2018 (see Section 6.0) and dry weather Pesticides and Toxicity monitoring in WY 2017.

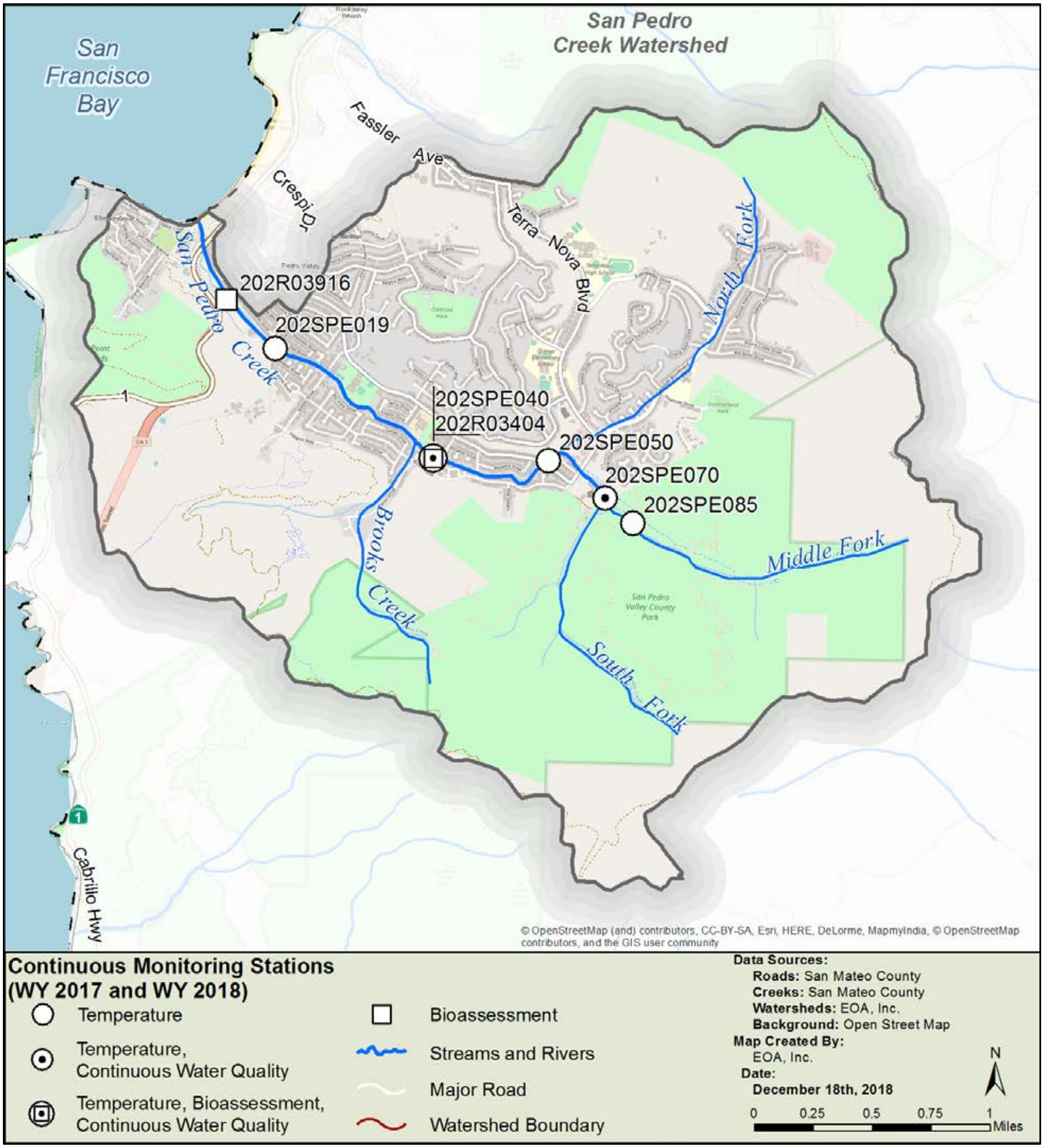


Figure 3.1. Continuous temperature and water quality stations in the San Pedro Creek watershed, San Mateo County, WY 2018.

3.3 Methods

Water quality data were collected in accordance with SWAMP-comparable methods and procedures described in the BASMAA RMC SOPs (BASMAA 2016b) and associated QAPP (BASMAA 2016a). Data were evaluated with respect to the MRP Provision C.8.d “Follow-up” triggers for each parameter.

3.3.1 Continuous Temperature

Digital temperature loggers (Onset HOBO Water Temp Pro V2) programmed to record data at 60-minute intervals. The loggers were deployed at targeted sites from April 5 through September 25, 2018. Procedures used for calibrating, deploying, programming and downloading data are described in RMC SOP FS-5 (BASMAA 2016b).

3.3.2 Continuous General Water Quality

Water quality monitoring equipment recording dissolved oxygen, temperature, conductivity, and pH(YSI 6600 data sondes) were programmed to record data at 15-minute intervals. The sondes were deployed at targeted sites for two 2-week periods: once during spring season (Event 1) and once during summer season (Event 2) in 2018. Procedures used for calibrating, deploying, programming and downloading data are described in RMC SOP FS-4 (BASMAA 2016b).

3.3.3 Data Evaluation

Continuous temperature and water quality data generated during WY 2018 were analyzed and evaluated to identify potential stressors that may be contributing to degraded or impacted biological conditions, including exceedances of water quality objectives. Provision C.8.d of the MRP identifies trigger criteria as the principal means of evaluating the creek status monitoring data to identify sites where water quality impacts may have occurred. Sites with targeted monitoring results exceeding the trigger criteria are identified as candidate SSID projects. The relevant trigger criteria for continuous temperature and water quality data are listed in Table 3.1.

Table 3.1. Water Quality Objectives and thresholds used for trigger evaluation.

Monitoring Parameter	Objective/Trigger Threshold	Units	Source
Temperature	Two or more weekly average temperatures exceed the MWAT of 17.0°C for a Steelhead stream, or when 20% of the results at one sampling station exceed the instantaneous maximum of 24°C.	^{o}C	MRP Provision C.8.d.iii.
General Water Quality Parameters	20% of results at each monitoring site exceed one or more established standard or threshold - applies individually to each parameter		
Conductivity	2000	uS/cm	MRP Provision C.8.d.iii.
Dissolved Oxygen	WARM < 5.0, COLD < 7.0	mg/L	SF Bay Basin Plan Ch. 3, p. 3-4
pH	> 6.5, < 8.5 [1]	pH	SF Bay Basin Plan Ch. 3, p. 3-4
Temperature	Same as Temperature (See Above)		

[1] Special consideration will be used at sites where imported water is naturally causing higher pH in receiving waters.

3.4 Results and Discussion

The section below summarizes results from continuous temperature and water quality monitoring conducted during WY 2018. Conclusions and recommendations for this section are presented in Section 7.0.

3.4.1 Continuous Temperature

Temperature loggers were deployed at five sites in the San Pedro Creek watershed on April 5, checked and downloaded on June 21, and removed on September 25, 2018. During the field check in June, the temperature logger at site 202SPE019 was not recovered, and another logger was re-deployed. As a result, only 13 weeks of data were recorded at that site.

Summary statistics for continuous water temperature data collected at the five sites are listed in Table 3.2. None of the recorded temperatures exceeded the instantaneous maximum temperature trigger of 24°C.

Table 3.2 Descriptive statistics for continuous water temperature measured between April 5 through September 25, 2018 at five sites in San Pedro Creek, San Mateo County.

Site ID (202SPE)		019	040	050	070	085
Start Date		6/21/2018	4/5/2018	4/5/2018	4/5/2018	4/5/2018
End Date		9/24/2018	9/25/2018	9/25/2018	9/25/2018	9/25/2018
Temperature (ºC)	Minimum	11.4	10.9	11.3	9.4	9.0
	Median	15.2	14.2	14.2	13.1	13.3
	Mean	15.3	14.3	14.2	13.1	13.3
	Maximum	18.9	17.9	17.0	16.0	18.0
	Max 7-day mean	16.7	16.1	15.7	14.7	15.9
	N (# individual measurements)	2204	4149	4150	4148	4149
# Measurements > 24°C		0	0	0	0	0

Maximum Weekly Average Temperature (MWAT) values were calculated for each of the five monitoring sites (Table 3.3). Consistent with MRP requirements, the MWAT was calculated for non-overlapping, seven-day periods. The MWAT values across all the sites ranged from 10.7 °C to 13.4 °C during the month of April to 13.3 °C to 15.7°C during the month of August. Time series plots of the MWAT values are shown for all five sites in San Pedro Creek (Figure 3.2). Similar to the results from WY 2017, the MWAT trigger was never exceeded at any of the sites.

Table 3.3. MWAT values for water temperature data collected at five stations monitored in San Pedro Creek watershed, WY 2018. MRP trigger is 17°C.

Station	202SPE019	202SPE040	202SPE050	202SPE070	202SPE085
Date	Maximum Weekly Average Temperature (°C)				
4/5/2018		13.1	13.1	12.1	11.9
4/12/2018		12.3	12.4	11.0	10.7
4/19/2018		12.8	12.9	11.5	11.1
4/26/2018		13.3	13.4	12.1	11.7
5/3/2018		13.5	13.6	12.2	11.9
5/10/2018		13.8	13.9	12.6	12.4
5/17/2018		13.4	13.6	12.4	12.0
5/24/2018		13.8	13.8	12.6	12.3
5/31/2018		13.7	13.7	12.4	12.2
6/7/2018		14.0	14.0	12.9	12.7
6/14/2018		14.2	14.1	13.0	13.1
6/21/2018	14.8	14.5	14.3	13.2	13.4
6/28/2018	15.4	14.9	14.6	13.6	13.9
7/5/2018	15.8	15.2	14.9	13.8	14.5
7/12/2018	16.3	15.7	15.3	14.3	15.3
7/19/2018	16.7	16.1	15.7	14.7	15.9
7/26/2018	14.6	14.6	14.6	13.7	14.4
8/2/2018	14.7	14.4	14.3	13.3	13.8
8/9/2018	15.4	14.9	14.8	13.8	14.3
8/16/2018	15.5	15.2	15.0	14.0	14.7
8/23/2018	15.7	15.3	15.2	14.2	14.9
8/30/2018	15.3	15.2	15.1	14.0	14.7
9/6/2018	14.6	14.4	14.4	13.3	13.5
9/13/2018	14.7	14.6	14.6	13.6	13.9
9/20/2018		13.3	13.4	12.2	11.9
Total Weeks	13	25	25	25	25
MWAT >17	0	0	0	0	0
% Exceed	0%	0%	0%	0%	0%
> MRP Trigger	N	N	N	N	N

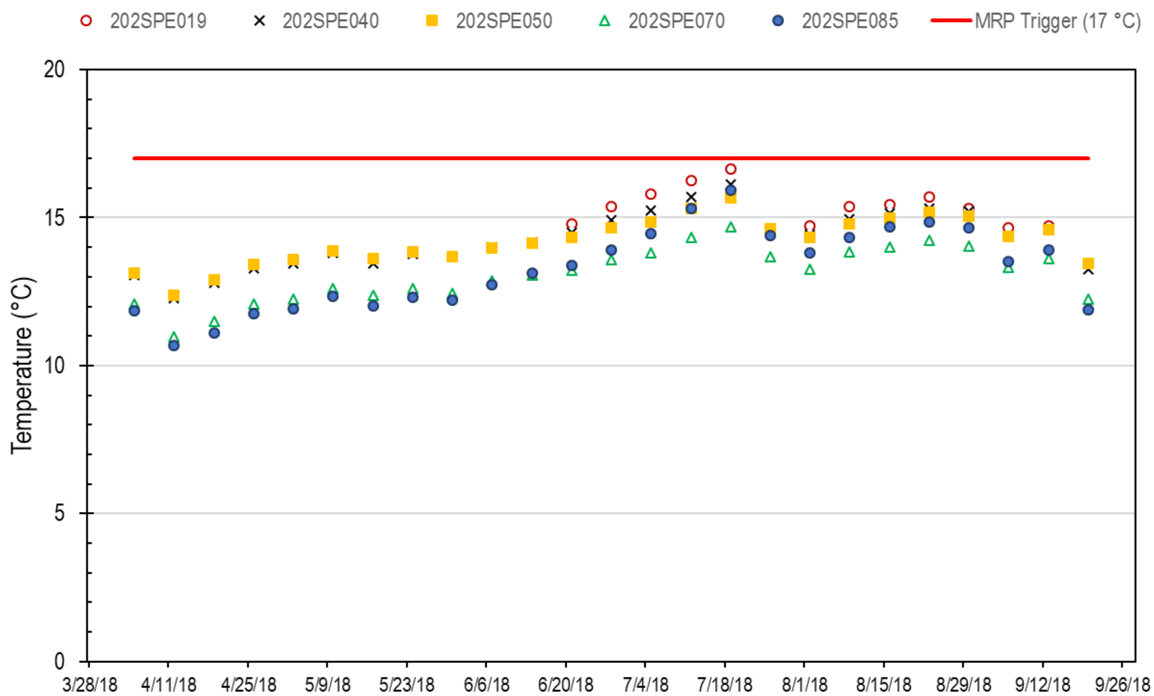


Figure 3.2. Maximum Weekly Average Temperature (MWAT) values calculated for water temperature collected at five sites in San Pedro Creek over 26 weeks of monitoring in WY 2018. The MRP trigger (17°C) is shown for comparison.

Water temperature data, calculated as a daily average, for monitoring sites in San Pedro Creek collected during WY 2018, are shown in Figure 3.3. Daily average temperatures for data collected in WY 2017 are also presented for comparison. In WY 2018, water temperatures generally increased from the start of the monitoring period through the end of August followed by a slow decline in early September. Water temperatures showed a similar pattern in 2017, with the exception of a period of high temperatures observed during the month of September, reflecting the occurrence of a heatwave that exhibited some of the highest air temperatures on record.

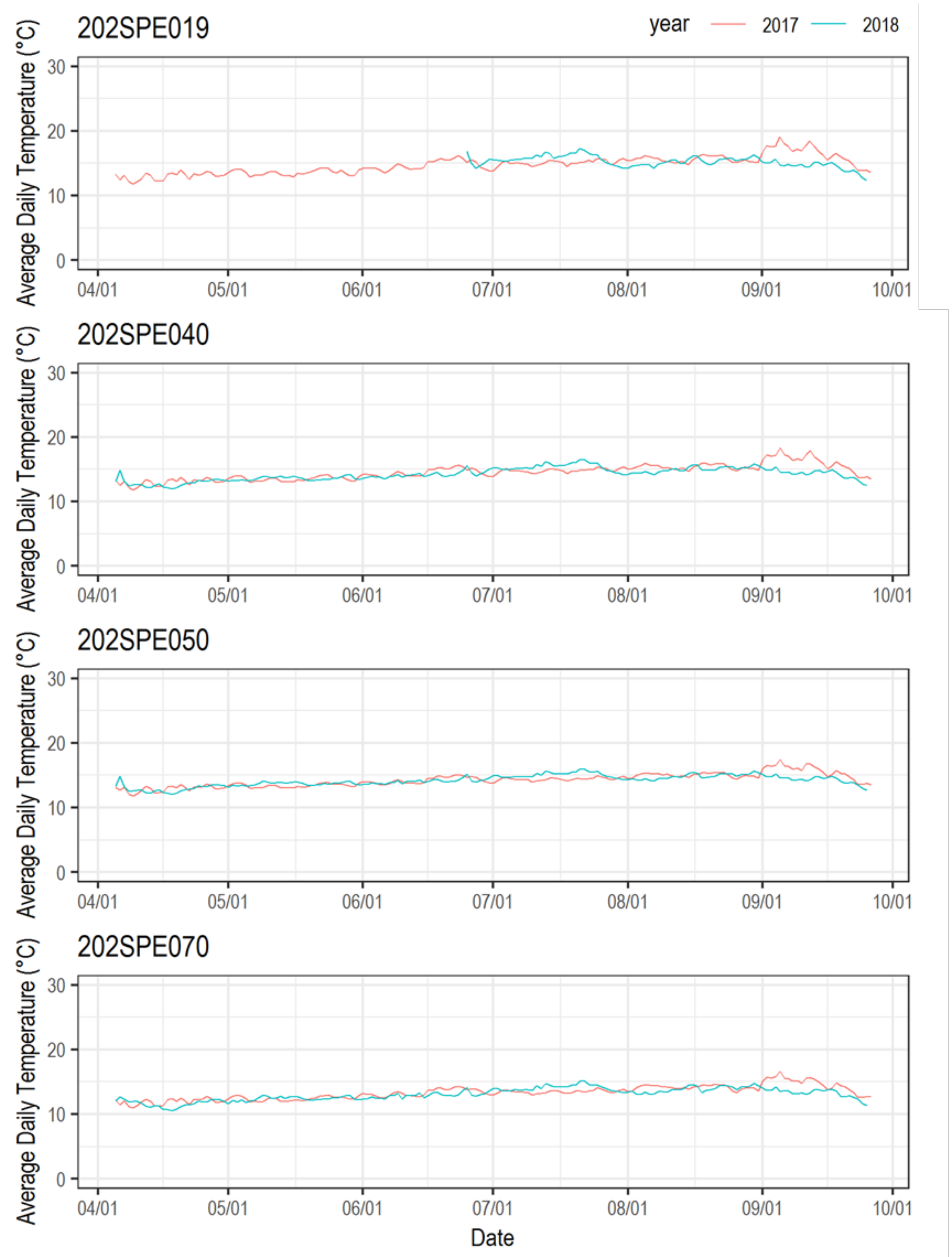


Figure 3.3 Water temperature, shown as daily average, collected between April and September 2017 and 2018 at five sites in San Pedro Creek, San Mateo County.[20]

[20] Datalogger at site 019 was not recovered during field check in June; data was collected June – September.

Instantaneous water temperatures collected at monitoring sites in San Pedro Creek for both years, are presented as bean plots in Figure 3.4. The pattern for water temperatures across all sites was relatively consistent for both years, with the median temperature generally increasing with decreasing site elevation.

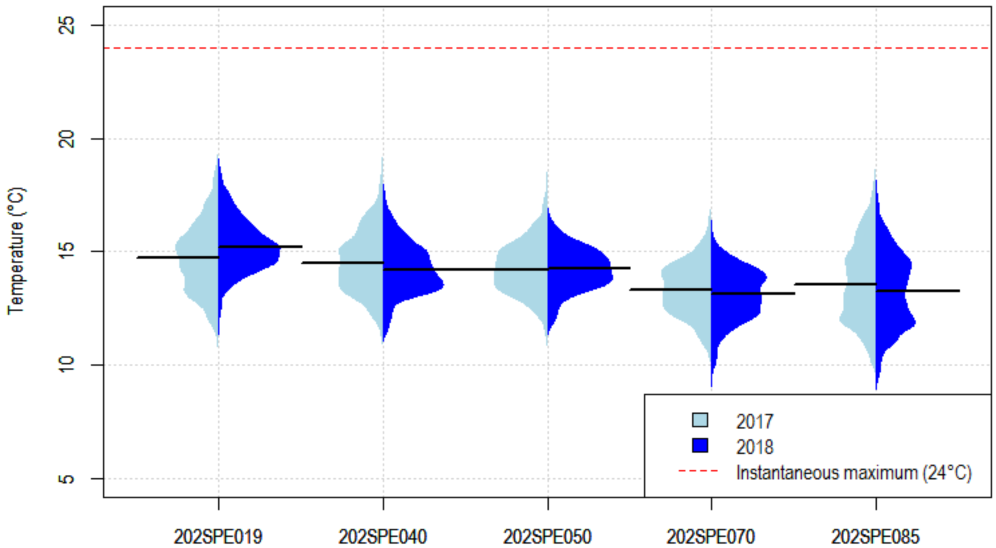


Figure 3.4. Water temperature data, presented as bean plots, collected between April and September at five sites in San Pedro Creek during WY 2017 and WY 2018. Solid black lines indicate median temperature.

The Basin Plan (SFRWQCB 2017) designates several Beneficial Uses for San Pedro Creek that are associated with aquatic life uses, including COLD, WARM, MIGR, SPWN and RARE (Table 1.4). Rearing and spawning habitat for steelhead trout is supported predominantly though the habitat of the protected Middle Fork San Pedro Creek. The restored section of the main stem of the creek is best suited for rearing to smolt size. Measured water quality and temperature are likely not limiting factors for steelhead trout in San Pedro Creek.

3.4.2 General Water Quality

Summary statistics for general water quality measurements collected at the two stations in San Pedro Creek are listed in Table 3.4. Station locations are mapped in Figure 3.1. For Event 1, sondes were deployed on May 4 and retrieved on May 17, 2018. For Event 2, sondes were deployed on August 10 and retrieved on August 21, 2018.

Table 3.4. Descriptive statistics for continuous water temperature, dissolved oxygen, pH, and specific conductance measured at two San Pedro Creek sites in San Mateo County during WY 2018. Data were collected every 15 minutes over a two 2-week time periods during May (Event 1) and August (Event 2).

Parameter	Data Type	202SPE040		202SPE070	
		Event 1 WY18	Event 2 WY18	Event 1 WY18	Event 2 WY18
Temperature (°C)	Minimum	12.1	13.7	10.9	11.6
	Median	13.6	15.1	12.4	14
	Mean	13.7	15.1	12.4	13.8
	Maximum	15.6	16.8	13.9	15.1
	% > 24	0%	0%	0%	0%
Dissolved Oxygen (mg/L)	Minimum	9.7	8.7	10.2	9.8
	Median	10.3	9.4	10.6	10
	Mean	10.3	9.4	10.6	10
	Maximum	10.7	9.9	11	10.6
	% < 7	0%	0%	0%	0%
pH	Minimum	7.99	7.7	7.57	7.68
	Median	8.19	7.9	7.87	7.78
	Mean	8.18	7.89	7.87	7.77
	Maximum	8.3	8.07	7.95	7.9
	% < 6.5 or > 8.5	0%	0%	0%	0%
Specific Conductivity (uS/cm)	Minimum	438	390	266	218
	Median	464	399	273	225
	Mean	464	401	273	226
	Maximum	475	490	283	235
	% > 2000	0%	0%	0%	0%
Total number of data points (N)		1229	1039	1191	858

Time series plots of the data for Event 1 and Event 2 are shown in Figures 3.5 and 3.6, respectively. MRP trigger thresholds are shown for reference. Water temperature distributions during Event 2 during WY 2017 and WY 2018 are plotted in Figure 3.7.

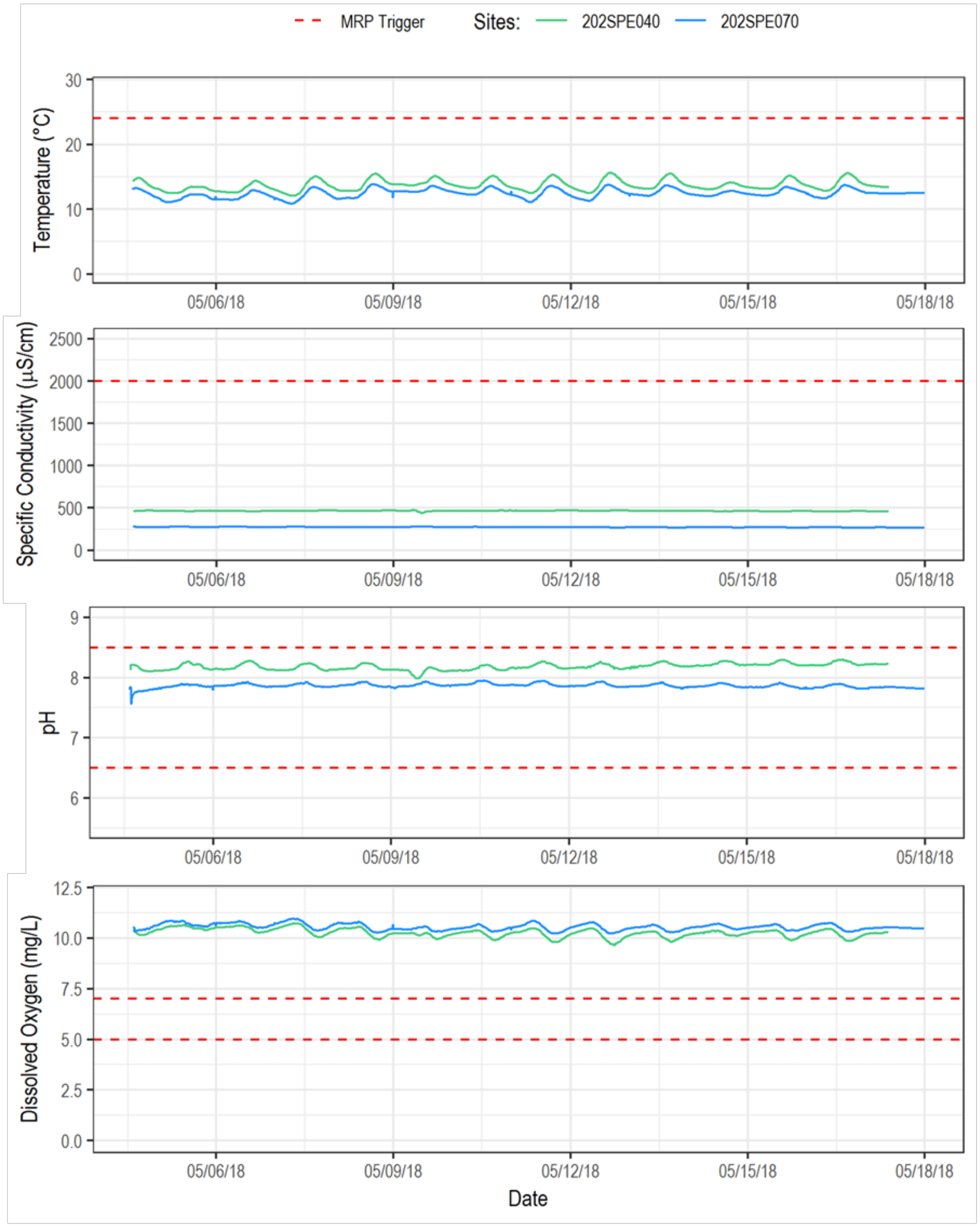


Figure 3.5 Continuous water quality data (temperature, specific conductance, pH, and dissolved oxygen) collected during May 4 – May 17, 2018 (Event 1) at two sites in San Pedro Creek watershed.

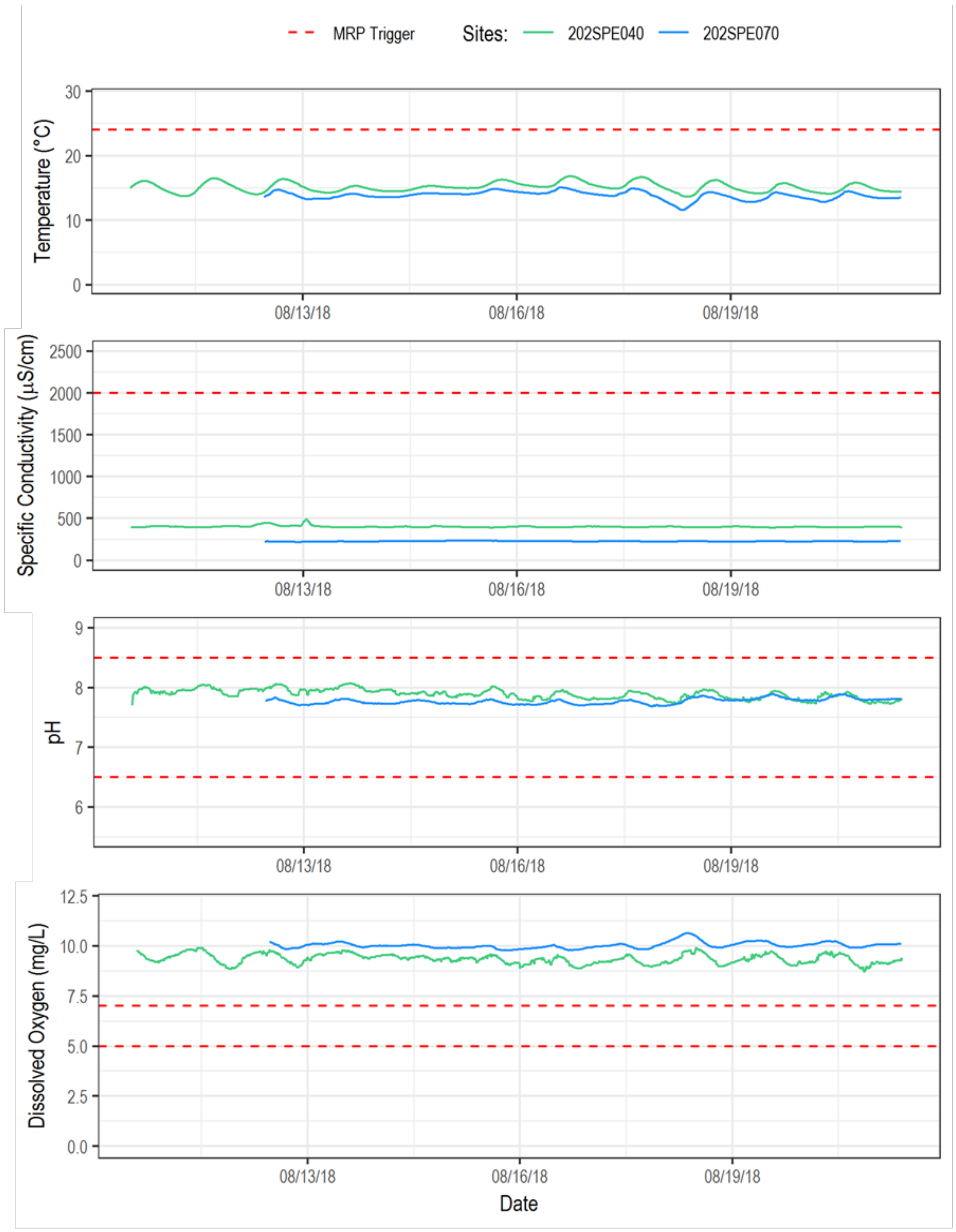


Figure 3.6 Continuous water quality data (temperature, specific conductance, pH, and dissolved oxygen) collected during August 10 – 20, 2018 (Event 2) at two sites in San Pedro Creek watershed.

Temperature

Water temperatures recorded by the sondes never exceeded the 24°C MRP trigger threshold for instantaneous maximum temperature at either site for both sampling events (Figures 3.5 and 3.6). The water temperature data collected by temperature loggers were used to evaluate MWAT (see previous section). As previously stated, the MWAT threshold of 17°C was not exceeded at any of the San Pedro Creek stations.

Specific Conductivity

Specific conductance measurements did not exceed the MRP trigger of 2000 µs/cm during either sampling event. Conductivity was slightly higher at the downstream station (202SPE040) compared to the upstream station (202SPE070). (Figures 3.5 and 3.6). The site is located in a more urbanized part of the creek, and run-off from the surrounding land uses may contribute to the higher specific conductance.

pH

During the two sampling events, all pH measurements fell within the Basin Plan WQOs for pH (< 6.5 and/or > 8.5). Similar to specific conductance, the pH was slightly higher at the downstream site (202SPE040) compared to the upstream station (202SPE070) (Figures 3.5 and 3.6).

Dissolved Oxygen

Dissolved oxygen (DO) concentrations were above the Basin Plan minimum WQOs for WARM (5.0 mg/L) and COLD (7.0 mg/L) at both sites during both sampling events. DO concentrations were similar at both locations, ranging between 8.7 mg/L and 11.0 mg/L (Figures 3.5 and 3.6). The high concentrations are likely a result of the consistent flows observed at both locations during WY 2017, which are supported by several springs in the upper watershed.

4.0 Pathogen Indicator Monitoring

4.1 Introduction

During WY 2018, pathogen indicators were monitored in compliance with Creek Status Monitoring Provision C.8.d.v of the MRP. Monitoring was conducted at sites selected using a targeted design based on the directed principle to address the following management question:

1. *What are the pathogen indicator concentrations at creek sites where there is potential for water contact recreation to occur?*

This management question is addressed primarily through the evaluation of targeted data with respect to trigger thresholds identified in the MRP. Sites where exceedances occur may indicate potential impacts to aquatic life or other beneficial uses and are considered as candidates for future Stressor/Source Identification projects.

4.2 Study Area

In compliance with Provision C.8.d.v of the MRP, pathogen indicator samples were collected during one sampling event (July 27, 2018) at five sites. The selection of sites was based on information on previous sampling results showing high bacteria concentrations that was provided by San Mateo County Parks staff (Figure 4.1). All sites were located in the Pescadero Creek watershed in the vicinity of Memorial County Park. Two sites were located on tributaries to Pescadero Creek: Jones Gulch (202PES150) and McCormick Creek (202PES142). Three sites were located on the main stem of Pescadero Creek upstream and downstream of the confluences with the two sampled tributaries. The sites were selected with coordination from San Mateo County Park staff to characterize geographic patterns of pathogen indicator densities within the Pescadero Creek watershed.

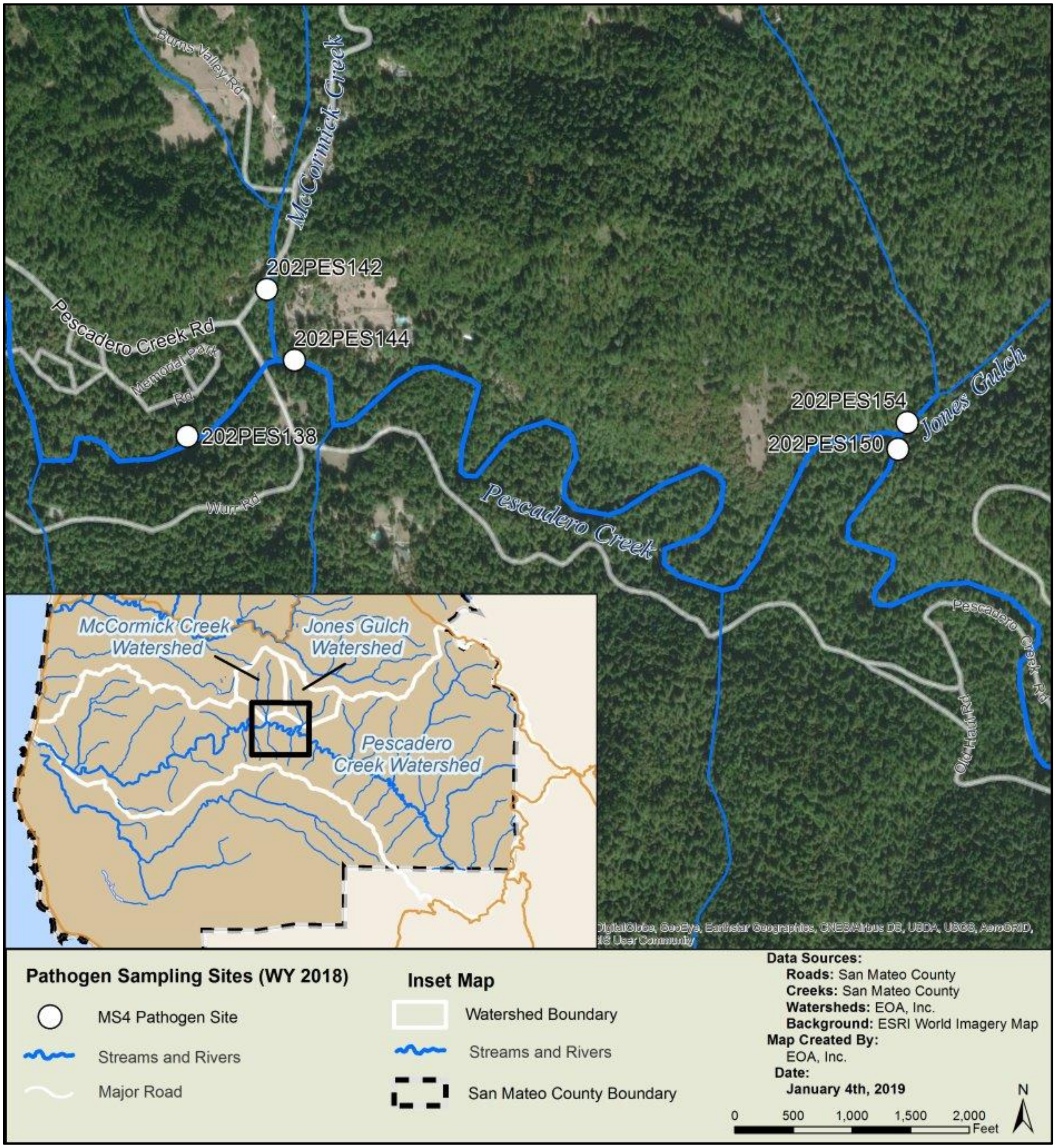


Figure 4.1. Pathogen indicator monitoring sites in WY 2018, Pescadero Creek Watershed.

4.3 Methods

Pathogen indicator data were collected during the dry season in accordance with SWAMP-comparable methods and procedures described in the BASMAA RMC SOPs (BASMAA 2016b) and associated QAPP (BASMAA 2016a). Sampling techniques for pathogen indicators (enterococci and *E. coli*) include direct filling of containers (or use of intermediate sampling containers) and transfer of samples to analytical laboratories within specified holding time requirements. Procedures used for sampling and transporting samples are described in RMC SOP FS-2 (BASMAA 2016b).

Pathogen indicator data generated during WY 2018 were evaluated with respect to MRP Provision C.8.d.v "Followup" triggers to identify potential impacts to water contact recreation (REC-1). The relevant trigger criteria for pathogen indicator data is based on USEPA (2012) recommended statistical threshold value for an estimated illness rate of 36 per 1000 primary contact recreators. For *E. coli*, the trigger threshold is 410 cfu/100 mL. For enterococcus, the trigger threshold is 130 cfu/100 mL. Sites with monitoring results exceeding the trigger criteria are identified as candidate SSID projects.

4.4 Results and Discussion

The section below summarizes results from pathogen indicator monitoring conducted during WY 2018. Conclusion and recommendations for this section are presented in Section 7.0.

Pathogen indicator (*E. coli* and enterococci) densities measured in grab samples collected on July 27, 2018 are listed in Table 3.1. Stations are mapped in Figure 4.1. There were no measurements that exceeded the MRP trigger for *E. coli*; however, two samples exceeded the MRP trigger for enterococci. The enterococci trigger exceedances were observed in McCormick Creek (202PES142) and Pescadero Creek at Memorial Park downstream of the McCormick confluence (202PES138). These sites will be added to the list of candidate SSID sites. It appears likely that McCormick Creek discharges were affecting water quality in Pescadero Creek on July 27, 2018. Potential sources of pathogen indicators include, but are not limited to, pet waste, wildlife, bacterial growth within the creekbed and conveyance systems, and leaking public and private sewer lines or onsite wastewater treatment systems.

It is important to recognize that pathogen indicators do not directly represent actual pathogen concentrations and do not distinguish among sources of bacteria. Testing water samples for specific pathogens is generally not practical for a number of reasons (e.g., concentrations of pathogens from fecal contamination may be small and difficult to detect but still of concern, laboratory analysis is often difficult and expensive, and the number of possible pathogens to potentially test for is large). Therefore, the presence of pathogens is inferred by testing for "pathogen indicator" organisms. The USEPA recommends using *E. coli* and enterococci as indicators of fecal contamination based on historical and recent epidemiological studies (USEPA 2012). The USEPA pathogen indicator thresholds were derived based on human recreation at beaches receiving bacteriological contamination from human wastewater, and may not be applicable to conditions in urban creeks which do not receive wastewater treatment plant discharges. Furthermore, although animal fecal waste contributes to the pathogen indicator load, it is much less likely to contain pathogens of concern to human health than human sources. In most cases, it is the human sources that are associated with REC-1 health risks rather than wildlife or domestic animal sources (USEPA 2012). As a result, the comparison of pathogen indicator results to pathogen indicator thresholds may not be appropriate and should be interpreted cautiously.

The State Water Board recently (August 7, 2018) adopted new WQOs for *E. coli* and enterococci based on USEPA (2012) criteria. The new WQOs, which are based on an estimated illness rate of 32 per 1000 primary contact recreators, will become effective upon approval by the Office of Administrative Law and the USEPA. [21] For freshwaters (i.e., salinity equal to or less than 1 part per thousand (ppth) 95 percent of the year), the six-week rolling geometric mean of *E. coli* must not exceed 100 cfu/100 mL; and the statistical threshold value (STV) of 320 cfu/100 mL must not be exceeded by more than 10 percent of samples collected in a calendar month. For marine and brackish waters (i.e., salinity greater than 1 ppth more than 5 percent of the year), the six-week rolling geometric mean of enterococci must not exceed 30 cfu/100 mL; and the STV of 110 cfu/100 mL must not be exceeded by more than 10 percent of samples collected in a calendar month. These thresholds are included in Table 3.1 for reference.

Table 4.1. Enterococci and *E. coli* levels measured in San Mateo County during WY 2018 (July 27, 2018).

Site ID	Creek Name	Site Name	*Enterococci (cfu/100ml) (MPN/100ml)*[1]	*E. Coli (cfu/100ml) (MPN/100ml)*[1]
MRP Trigger Threshold (USEPA 2012; 36 per 1000 recreators)			*130*	*410*
Newly Adopted WQO (based on 32 per 1000 recreators)			*110*	*320*
202PES154	Pescadero Creek	Pescadero Creek Upstream of Jones Gulch	43	30
202PES150	Jones Gulch	Jones Gulch Upstream of Confluence	36	ND
202PES144	Pescadero Creek	Pescadero Creek Upstream of McCormick Creek	42	19
202PES142	McCormick Creek	McCormick Creek Upstream of Confluence	816	153
202PES138	Pescadero Creek	Pescadero Creek at Memorial Park	435	14

[21] See http://www.waterboards.ca.gov/bacterialobjectives/ for more information.

5.0 Chlorine Monitoring

5.1 Introduction

Chlorine is added to potable water supplies and wastewater to kill microorganisms that cause waterborne diseases. However, the same chlorine can be toxic to the aquatic species. Chlorinated water may be inadvertently discharged to the MS4 and/or urban creeks from residential activities, such as pool dewatering or over-watering landscaping, or from municipal activities, such as hydrant flushing or water main breaks.

In compliance with Provision C.8.d.ii of the MRP and to assess whether chlorine in receiving waters is potentially toxic to aquatic life, SMCWPPP field staff measured total and free chlorine residual in creeks where bioassessments were conducted. Total chlorine residual is comprised of combined chlorine and free chlorine, and is always greater than or equal to the free chlorine residual. Combined chlorine is chlorine that has reacted with ammonia or organic nitrogen to form chloramines, while free chlorine is chlorine that remains unbound.

5.2 Methods

In accordance with the BASMAA RMC Creek Status and Long-Term Trends Monitoring Plan (BASMAA 2012), WY2018 field testing for free chlorine and total chlorine residual was conducted at all ten probabilistic sites concurrent with spring bioassessment sampling (May). Probabilistic site selection methods are described in Section 2.0.

Field testing for free chlorine and total chlorine residual conformed to methods and procedures described in the BASMAA RMC SOPs (BASMAA 2016b), which are comparable to those specified in the SWAMP QAPP. Per SOP FS-3 (BASMAA 2016b), water samples were collected and analyzed for free and total chlorine using a Pocket Colorimeter™ II and DPD Powder Pillows, which has a manufacturer reported method detection limit of 0.02 mg/L. If concentrations exceed the MRP trigger criteria of 0.1 mg/L, the site was immediately resampled. Per Provision C.8.d.ii(4) of the MRP, "if the resample is still greater than 0.1 mg/L, then Permittees report the observation to the appropriate Permittee central contact point for illicit discharges so that the illicit discharge staff can investigate and abate the associated discharge in accordance with its Provision C.5.e – Spill and Dumping Complaint Response Program."

5.3 Results and Discussion

The section below summarizes results from chlorine monitoring conducted during WY 2018. Conclusion and recommendations for this section are presented in Section 7.0.

In WY 2018, SMCWPPP monitored the ten probabilistic sites for free chlorine and total chlorine residual. These measurements were compared to the MRP trigger threshold of 0.1 mg/L. Results are listed in Table 5.1. The trigger thresholds for free chlorine and total chlorine residual were not exceeded during sampling in WY2018. This indicates that the chlorine levels in the sampled creeks were not of concern during this time frame.

For unknown reasons, the free chlorine result was greater than the total residual chlorine result at one station (202R03624). Potential causes for these inverted results include matrix interferences and colorimeter user error. According to Hach, the supplier of the equipment and reagents, the free chlorine could have false positive results due to a pH exceedance of 7.6 and/or an alkalinity exceedance of 250 mg/L. The pH was measured concurrently with the chlorine sample, but alkalinity was not measured. The pH measured concurrently with chlorine at station 202R03624 exceeded 7.6, which have resulted in a false positive for the free chlorine measurement. It is unlikely that the higher free chlorine readings were caused by user error. The field crew is well trained and aware of potential problems with this testing method, such as wait times between adding reagents and taking the readings and separating the free chlorine and total residual chlorine samples. Overall, the cause of the inverted free chlorine and total chlorine residual results (compared to expected) is unknown. However, it should be noted that colorimetric field instruments are generally not capable of providing accurate measurements of free chlorine and total chlorine residual below 0.13 mg/L, regardless of the method detection limit provided by the manufacturer. For this reason, the Statewide General Permit for drinking Water Discharges (Order WQ 2014-0194-DWQ) uses 0.1 mg/L as a reporting limit for field measurements of total chlorine residual.

Table 5.1. Summary of SMCWPPP chlorine testing results compared to MRP trigger of 0.1 mg/L, WY 2018.

Station Code	Date	Creek	Free Chlorine (mg/L)[1,2]	Total Residual Chlorine (mg/L)[1,2]	Exceeds Trigger Threshold? (0.1 mg/L)[2]
202R00614	5/14/2018	Pescadero Creek	0.03	0.05	No
202R00584	5/15/2018	Pilarcitos Creek	<0.02	<0.02	No
202R03656	5/15/2018	Pilarcitos Creek	<0.02	<0.02	No
204R03508	5/16/2018	Mills Creek	<0.02	<0.02	No
204R03528	5/16/2018	San Mateo Creek	0.03	0.03	No
202R03404	5/17/2018	San Pedro Creek	<0.02	<0.02	No
202R03916	5/17/2018	San Pedro Creek	<0.02	0.06	No
205R03624	5/21/2018	Bear Creek	0.07	0.01	No
202R03880	5/22/2018	La Honda Creek	NS	NS	NA
205R03864	5/22/2018	Hamms Gulch	NS	NS	NA

[1] The method detection limit is 0.02 mg/L; however, the Statewide General Permit for Drinking Water Discharges (Order WQ 2014-0194-DWQ) uses 0.1 mg/L as a reporting limit (minimum level) for field measurements of total chlorine residual.
[2] The MRP trigger threshold of 0.1 mg/L applies to both free chlorine and total chlorine residual measurements
NS= Not Sampled due to failed battery in Pocket Colorimeter™ II instrument. NA = Not Applicable.

A total of 70 stations have been monitored by SMCWPPP for free chlorine and total chlorine residual between WY 2012 and WY 2018 in compliance with MRP 1.0 and MRP 2.0. Occasional exceedances were recorded throughout the years and addressed by the appropriate follow-up process. Figure 4.1 maps of all the samples stations with their associated results. The results exceeding the 2015 MRP 20 trigger threshold of 0.1 mg/L are shown in red. The results exceeding 2009 MRP trigger threshold of 0.08 mg/L (but below the MRP 2.0 trigger) are shown in orange. All the results equal to or below 0.08 mg/L are shown in green. Trigger exceedances tend to occur in high order streams that flow through populated areas. The values range from non-detectable levels of chlorine to 0.58 mg/L. The two highest results occurred on Atherton Creek (WY 2017).

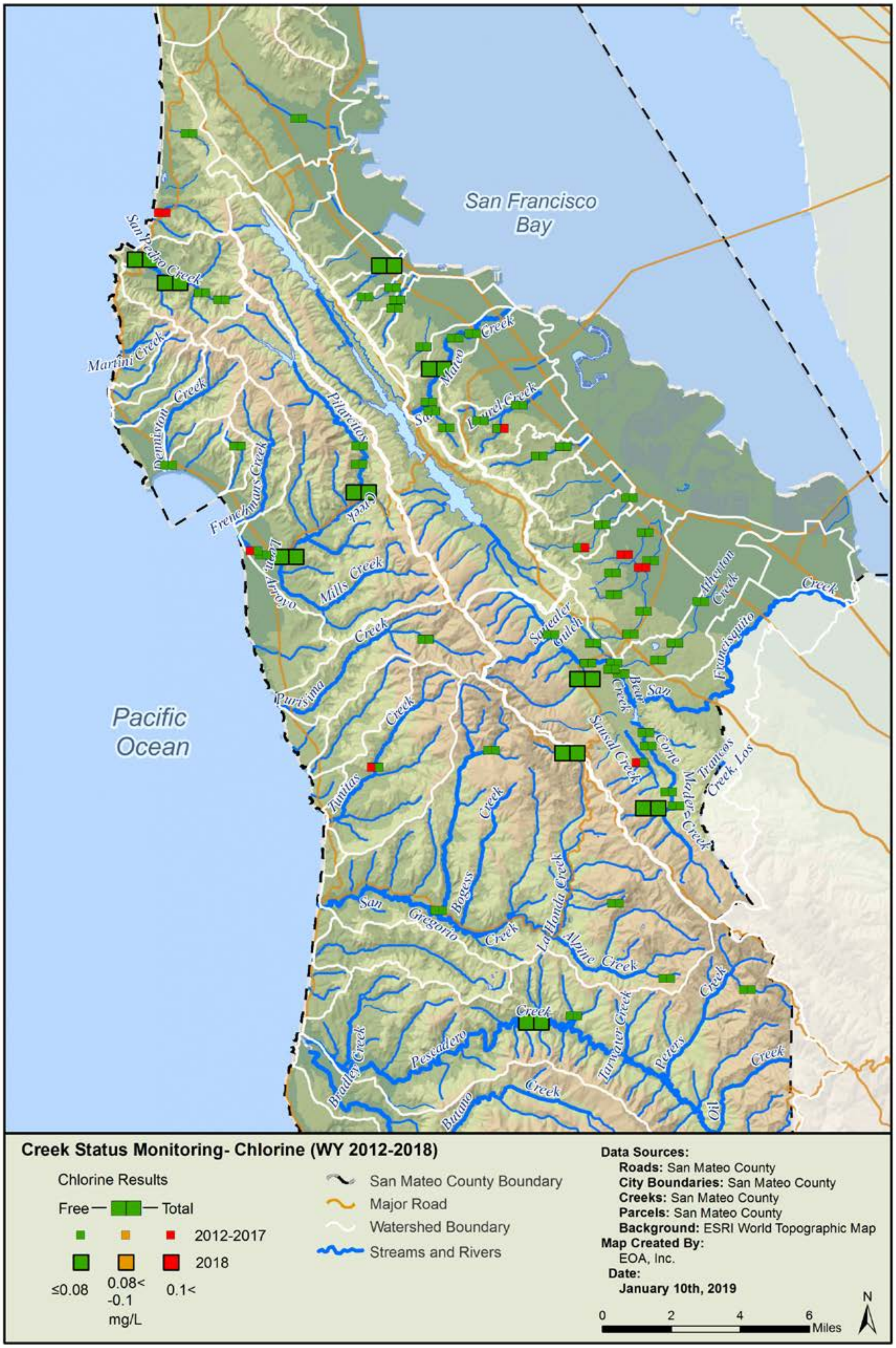


Figure 5.1 Chlorine sample stations WY 2012 – WY 2018 in San Mateo County.

6.0 Toxicity and Sediment Chemistry Monitoring

6.1 Introduction

Toxicity testing provides a tool for assessing the toxic effects (acute and chronic) of all chemicals in samples of receiving waters or sediments, and allows the cumulative effect of the pollutant present in the sample to be evaluated. Because different test organisms are sensitive to different classes of chemicals and pollutants, several different organisms are monitored. Sediment and water chemistry monitoring for a variety of potential pollutants conducted synoptically with toxicity monitoring provides preliminary insight into the possible causes of toxicity should they be found.

Provision C.8.g of the MRP requires both wet and dry weather monitoring of pesticides and toxicity in urban creeks.

Dry Weather

SMCWPPP is required to conduct water toxicity and sediment chemistry and toxicity monitoring at one location per year during the dry season, for each year of the permit term beginning in WY 2016. The permit provides examples of possible monitoring location types, including sites with suspected or past toxicity results, existing bioassessment sites, or creek restoration sites. Dry weather monitoring includes:

- Toxicity testing in water is required using five species: *Ceriodaphnia* dubia (chronic survival and reproduction), *Pimephales promelas* (larval survival and growth), *Selenastrum capricornutum* (growth), *Hyalella azteca* (survival) and *Chironomus dilutes* (survival).
- Toxicity testing in sediment is required using two species: *Hyella azteca* (survival) and *Chironomus dilutes* (survival).
- Sediment chemistry analytes include pyrethroids, fipronil, carbaryl, total polycyclic aromatic hydrocarbons (PAHs), metals, Total Organic Carbon (TOC), and sediment grain size.

Wet Weather

The wet weather monitoring requirements include collection of water column samples during storm events for toxicity testing (using the same five organisms required for dry weather toxicity testing) and analysis of pyrethroids, fipronil, imidacloprid and indoxacarb[22]. The MRP states that monitoring locations should be representative of urban watersheds (i.e., bottom of watersheds).

Provision C.8.g.iii.(3) requires a collective total of ten samples, with at least six samples collected by WY 2018, if the wet weather monitoring is conducted by the RMC on behalf of all Permittees. At the RMC Monitoring Workgroup meeting on January 25, 2016, RMC members agreed to collaborate on implementation of the wet weather monitoring requirements. All ten wet weather samples were collected in WY 2018 during a single storm event on January 8, 2018.

[22] Standard analytical methods for indoxacarb are not currently available. Indoxacarb analysis will not be required until the water year following notification by the Executive Officer that a method is available.

SCVURPPP and ACCWP each collected three samples, and SMCWPPP and CCCWP each collected two samples.

6.2 Methods

6.2.1 Site Selection

In WY 2018, in compliance with MRP Provisions C.8.g.i and C.8.g.ii, water and sediment toxicity and sediment chemistry samples were collected from one station during dry weather: Cordilleras Creek in the City of San Carlos (see Figure 6.1). The site was selected to represent mixed-land use in an urban watershed that is not already being monitored for toxicity or pesticides by other programs, such as the SWAMP Stream Pollution Trends (SPoT) program. The specific station within the watershed was identified based on the likelihood that they would contain fine depositional sediments during dry season sampling and would be safe to access during wet weather sampling. It is anticipated that SMCWPPP will select a different creek to target for dry weather pesticides and toxicity monitoring in future years of the permit term with the goal of building a geographically diverse dataset.

Additionally in WY 2018, in compliance with MRP Provision C.8.g.iii, water toxicity and pesticides samples were collected from two sites during wet weather: San Pedro Creek in the City of Pacifica and Cordilleras Creek near the City of San Carlos. San Pedro Creek was selected because it was monitored for dry weather pesticides and toxicity in WY 2017. Cordilleras Creek was selected because it was targeted for dry weather monitoring in WY 2018. The goal was to compare dry and wet weather monitoring results.

6.2.2 Sample Collection

Water samples for pesticides and toxicity were collected using standard grab sampling methods. The required number of labeled amber glass bottles were filled and placed on ice to cool to < 6C. The laboratory was notified of the impending sampling delivery to meet sample hold times. Procedures used for sampling and transporting water samples are described in SOP FS-2 (BASMAA 2016b).

Before conducting sediment sampling, field personnel surveyed the proposed sampling area for appropriate fine-sediment depositional areas. Personnel carefully entered the stream to avoid disturbing sediment at collection sub-sites. Sediment samples were collected from the top 2 cm at each sub-site beginning at the downstream-most location and continuing upstream. Sediment samples were placed in a compositing container, thoroughly homogenized, and then aliquoted into separate jars for chemical or toxicological analysis using standard clean sampling techniques (see SOP FS-6, BASMAA 2016b).

Sample were submitted to respective laboratories and field data sheets were reviewed per SOP FS-13 (BASMAA 2016b). The laboratory responsible for analyzing water column pesticide samples in WY 2018 (i.e., Physis Laboratory in Anaheim, CA) was selected by the RMC because it is capable of conducting analyses with reporting limits below the maximum threshold specified in MRP Provision C.8.g.iii.(1).

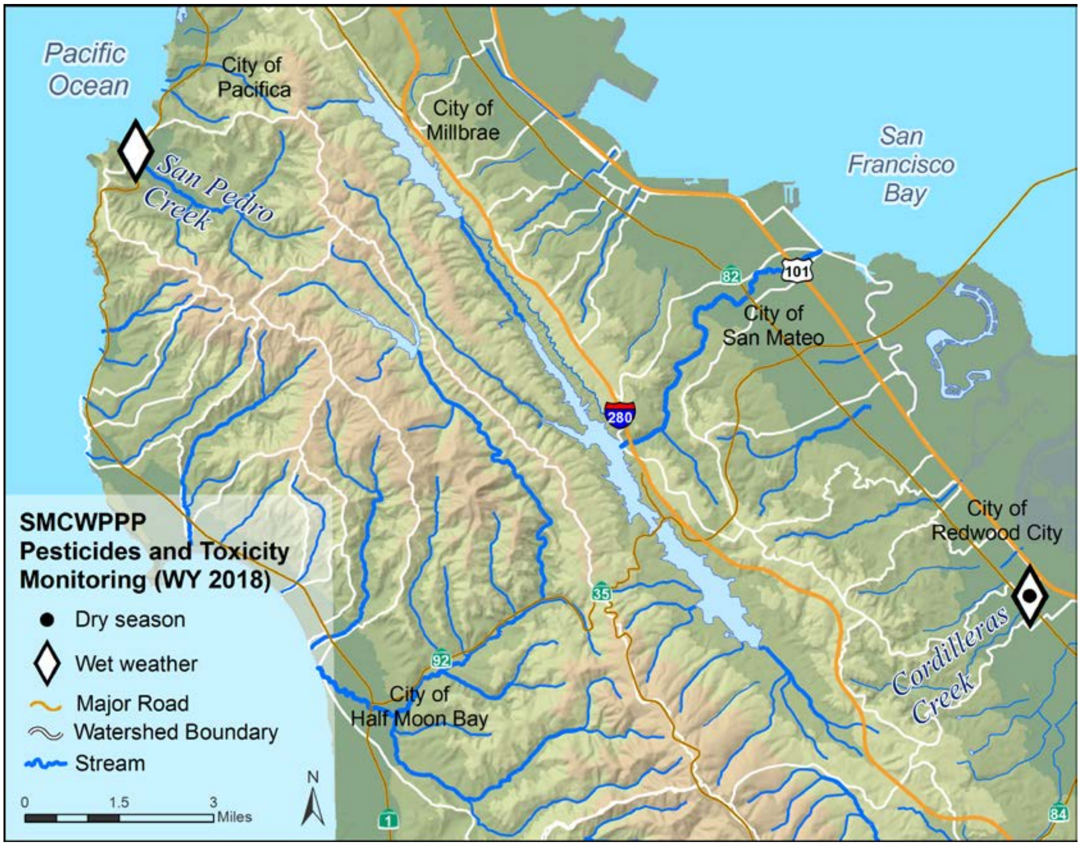


Figure 6.1 Pesticide and toxicity sampling locations in San Mateo County during WY 2018.

6.2.3 Data Evaluation

Water and Sediment Toxicity

Data evaluation required by the MRP involves first assessing whether the samples are toxic to the test organisms relative to the laboratory control treatment via statistical comparison using the Test of Significant Toxicity (TST) statistical approach. For samples with toxicity (i.e., those that "failed" the TST), the Percent Effect is evaluated. The Percent Effect compares sample endpoints (survival, reproduction, growth) to the laboratory control endpoints. Follow-up sampling is required if any test organism is reported as "fail" vis the TST approach *and* the Percent Effect is ≥ 50%. Both the TST result and the Percent Effect are determined by the laboratory. If both the initial and follow-up sample are reported as "fail" with ≥ 50% Percent Effect, the site is added to the list of candidate SSID projects.

Sediment Chemistry

In compliance with MRP Provision C.8.g.iv, sediment sample results are compared to Probable Effects Concentrations (PECs) and Threshold Effects Concentrations (TECs) as defined by MacDonald et al. (2000). PEC and TEC quotients are calculated as the ratio of the measured concentration to the respective PEC and TEC values from MacDonald et al. (2000). All results where a PEC or TEC quotient is equal to or greater than 1.0 are identified and added to the list of candidate SSID projects.

PECs and TECs are listed in MacDonald et al. (2000) for total PAHs, rather than the individual PAHs that are reported by the laboratory. Total PAH concentrations were calculated by summing the concentrations of 24 individual PAHs. Concentrations equal to one-half of the respective laboratory method detection limits were substituted for non-detect data so that calculations and statistics could be computed. Therefore, some of the TEC and PEC quotients may be artificially elevated (and contribute to trigger exceedances) due to the method used to account for non-detect data.

The TECs for bedded sediments are very conservative values that do not consider site specific background conditions, and are therefore not very useful in identifying real water quality concerns in receiving waters in the San Mateo County. All sites in the County are likely to have at least one TEC quotient equal to or greater than 1.0. This is due to high levels of naturally-occurring chromium and nickel in geologic formations (i.e., serpentinite) and soils that contribute to TEC and PEC quotients. These conditions will be considered when making decisions about SSID projects.

The current MRP does not require consideration of pyrethroid, fipronil, or carbaryl sediment chemistry data for follow-up SSID projects, perhaps because pyrethroids are ubiquitous in the urban environment and little is known about fipronil and carbaryl distribution. However, SMCWPPP computed toxicity unit (TU) equivalents for individual pyrethroid results, based on available literature values for pyrethroids in sediment LC50 values.[23,24] Because organic carbon mitigates the toxicity of pyrethroid pesticides in sediments, the LC50 values were derived on the basis of TOC-normalized concentrations. Therefore, the pesticide concentrations as reported by the lab were divided by the measured total organic carbon (TOC) concentration at each site, and the TOC-normalized concentrations were then used to compute TU equivalents for each constituent. Concentrations equal to one-half of the respective laboratory method detection limits were substituted for non-detect data so that these statistics could be computed, potentially resulting in artificially elevated results.

Water Chemistry

MRP Provision C.8.g.iv requires that chemical pollutant data from water and sediment monitoring be compared to the corresponding water quality objectives in the Basin Plan for each analyte sampled. If concentrations in the samples exceed their water quality objectives, then the site at which the exceedances were observed will be added to the list of candidate SSID projects. However, the Basin Plan does not contain numeric water quality objectives for the chemical analytes encompassed within the wet weather pesticide monitoring.

Due to the lack of numeric thresholds for these analytes, the data collected during the WY 2018 wet weather pesticide monitoring cannot be assessed to determine if the sampled sites should be added to the list of candidate SSID projects. However, there exist opportunities to compare and integrate wet weather pesticide monitoring data collected for MRP purposes with other similar data collected throughout the state. The California Department of Pesticide Regulation (DPR) Surface Water Protection Program Monitoring (SWPP) is one of the largest pesticide monitoring and management efforts currently being undertaken in California. Pesticide studies conducted by DPR make use of aquatic benchmarks set by the United States Environmental Protection Agency (USEPA) for many pesticide compounds, including all analytes targeted by

[23] The LC50 is the concentration of a given chemical that is lethal on average to 50% of test organisms.

[24] No LC50 is published for carbaryl in sediment.

MRP wet weather pesticide monitoring. DPR provides web access to a number of its monitoring reports which contain detailed analyses of USEPA aquatic benchmark exceedance rates. MRP pesticide data were compared to the USEPA benchmarks used by DPR to gain an understanding of how San Mateo County data compare to the larger dataset being developed by DPR; however, sites with USEPA aquatic benchmark exceedances were not added to the list of candidate SSID projects on that basis alone. DPR also maintains the Surface Water Database (SURF) to provide public access to quantitative pesticide data from a wide array of surface water monitoring studies. This database could be queried in the future to allow the leverage of DPR monitoring data in more complex analyses of MRP pesticide data.

6.3 Results and Discussion

Toxicity and pesticides monitoring results are described in the sections below. Conclusions and recommendations are provided in section 7.0.

6.3.1 Toxicity

Table 6.1 provides a summary of toxicity testing results for WY 2018 dry weather water and sediment samples. Table 6.2 provides a summary of toxicity testing results for WY 2018 wet weather water samples. Based on the WY 2018 toxicity monitoring results, it is not necessary to add Cordilleras Creek or San Pedro Creek to the list of potential SSID projects.

The dry weather water sample was significantly toxic to one of the five test organisms (*C. dilutus);* however, the Percent Effect did not exceed the 50% threshold for follow-up. The cause of the water toxicity is unknown. The sediment sample was not toxic to either of the test organisms.

The wet weather water sample collected in San Pedro Creek (202SPE005) was significantly toxic to two of the five test organisms (*P. promelas* and *H. azteca)*, while the sample collected in Cordilleras Creek (204COR010) was significantly toxic to one of the test organisms (*H. azteca*). However, the Percent Effect did not exceed the 50% threshold for follow-up at either site. The cause of the water toxicity is unknown.

Table 6.1. Summary of SMCWPPP dry weather water and sediment toxicity results, Cordilleras Creek, WY 2018.

Site	Organism	Test Type	Unit	Results: Lab Control	Results: Organism Test	% Effect	TST Value	Follow up needed (TST "Fail" and ≥50%)
204COR010 Cordilleras Creek July 17, 2018	Water							
	Ceriodaphnia dubia	Survival	%	100	100	0	NA[1]	No
		Reproduction	Num/Rep	23.8	33	-39	Pass	No
	Pimephales promelas	Survival	%	97.5	95	33	Pass	No
		Growth	mg/ind	0.916	0.905	1	Pass	No
	Chironomus dilutus	Survival	%	95	85	11	Fail	No
	Hyalella azteca	Survival	%	98	98	0	Pass	No
	Selenastrum capricornutum	Growth	cells/ml	4610000	8680000	-88	Pass	No
	Sediment							
	Chironomus dilutus	Survival	%	82.5	88.8	-88	Pass	No
	Hyalella azteca	Survival	%	92.5	95	-33	Pass	No

[1] TST analysis is not performed for survival endpoint - a percent effect <25% is considered a "Pass", and a percent effect ≥25% is considered a "Fail"

Table 6.2. Summary of SMCWPPP wet weather water toxicity results, San Pedro Creek and Cordilleras Creek, WY 2018.

Site	Organism	Test Type	Unit	Results		% Effect	TST Value	Follow up needed (TST "Fail" and ≥50%)
				Lab Control	Organism Test			
202SPE005 San Pedro Creek Jan 20, 2018	Water							
	Ceriodaphnia dubia	Survival	%	100	100	0	NA[1]	No
		Reproduction	Num/Rep	35	34.9	0.3	Pass	No
	Pimephales promelas	Survival	%	100	82.5	18	Pass	No
		Growth	mg/ind	0.791	0.612	23	Fail	No
	Chironomus dilutus	Survival	%	97.5	92.5	5	Pass	No
	Hyalella azteca	Survival	%	100	84	16	Fail	No
	Selenastrum capricornutum	Growth	cells/ml	2560000	4560000	-78	Pass	No
204COR010 Cordilleras Creek Jan 20, 2018	Water							
	Ceriodaphnia dubia	Survival	%	100	100	0	NA[1]	No
		Reproduction	Num/Rep	35	37.2	-6	Pass	No
	Pimephales promelas	Survival	%	100	95	5	Pass	No
		Growth	mg/ind	0.791	0.713	10	Pass	No
	Chironomus dilutus	Survival	%	97.5	97.5	0	Pass	No
	Hyalella azteca	Survival	%	100	80	20	Fail	No
	Selenastrum capricornutum	Growth	cells/ml	2560000	4830000	-88	Pass	No

[1] TST analysis is not performed for survival endpoint - a percent effect <25% is considered a "Pass", and a percent effect ≥25% is considered a "Fail"

6.3.2 Sediment Chemistry

Sediment chemistry results are evaluated as potential stressors based on TEC quotients and PEC quotients according to criteria in Provision C.8.g.iv of the MRP. SMCWPPP also evaluated TU equivalents of pyrethroids and fipronil.

Table 6.3 lists concentrations and TEC quotients for sediment chemistry constituents (metals and total PAHs). TEC quotients are calculated as the measured concentration divided by the highly conservative TEC value, per MacDonald et al. (2000)[25]. TECs are extremely conservative and are intended to identify concentrations below which harmful effects on sediment-dwelling organisms are unlikely to be observed. The site on Cordilleras Creek exceeded the relevant trigger criterion from the MRP of having at least one result exceeding the TEC and will be added to the list of potential SSID projects. However, the TEC exceedances were of chromium and nickel as expected in watersheds draining hillsides underlain by serpentinite formations.

Table 6.4 provides concentrations and PEC quotients for sediment chemistry constituents (metals and total PAHs). PECs are intended to identify concentrations above which toxicity to benthic-dwelling organisms are predicted to be probable. No PEC quotients were greater than 1.0.

Table 6.3. Threshold Effect Concentration (TEC) quotients for WY 2018 sediment chemistry constituents. Bolded and shaded values indicate TEC quotient ≥ 1.0.

	TEC	204COR010 Cordilleras Creek	
		Concentration	Quotient
Metals (mg/kg DW)			
Arsenic	9.79	4.1	0.42
Cadmium	0.99	0.12	0.12
Chromium	43.4	91	2.1
Copper	31.6	25	0.79
Lead	35.8	15	0.42
Nickel	22.7	92	4
Zinc	121	78	0.64
PAHs (ug/kg DW)			
Total PAHs	1,610	290	0.18 [a]

a. Total calculated using ½ MDLs.

[25] MacDonald et al. (2000) does not provide TEC or PEC values for pyrethroids, fipronil, or carbaryl. Pyrethroids are compared to LC50 values in Table 5.4. However, LC50 values for fipronil and carbaryl in sediment have not been published.

Table 6.4. Probable Effect Concentration (PEC) quotients for WY 2018 sediment chemistry constituents. Bolded and shaded values indicate PEC quotient ≥ 1.0.

	PEC	204COR010 Cordilleras Creek	
		Concentration	Quotient
Metals (mg/kg DW)			
Arsenic	33.0	4.1	0.12
Cadmium	4.98	0.12	0.024
Chromium	111	91	0.82
Copper	149	25	0.17
Lead	128	15	0.12
Nickel	48.6	92	1.9
Zinc	459	78	0.17
PAHs (ug/kg DW)			
Total PAHs	22,800	290	0.013 [a]

a. Total calculated using ½ MDLs.

Table 6.5 lists the concentrations of pesticides measured in sediment samples and calculated TOC-normalized TU equivalents for the pesticides for which there are published LC50 values in the literature. Most of the pesticides measured were below method detection limits (MDLs) and are listed as "<MDL" in Table 5.5. Others were below the reporting limits as noted in Table 5.4. The highest TU equivalent was for bifenthrin (0.251) which is considered to be the leading cause of pyrethroid-related toxicity in urban areas (Ruby 2013) and the most-commonly detected insecticide monitored by the DPR SWPP (Ensminger 2017). Except for bifenthrin, all of the calculated TU equivalents were less than 0.1.

Table 6.5. Pesticide concentrations and calculated toxic unit (TU) equivalents, WY 2018.

			204COR010 Cordilleras Creek			
	Unit	LC50[d]	Concen-tration	Normalized to TOC	TU Equivalent	
Total Organic Carbon	%	0.92				
Pyrethroid						
Bifenthrin	µg/g dw	0.52	0.00120	0.13	0.251	b
Cyfluthrin	µg/g dw	1.08	<0.00059	0.03	0.028	a
Cypermethrin	µg/g dw	0.38	<0.00053	0.028	0.073	a
Deltamethrin	µg/g dw	0.79	0.00069	0.075	0.095	b
Esfenvalerate	µg/g dw	1.54	<0.00069	0.036	0.024	a
Lambda-Cyhalothrin	µg/g dw	0.45	<0.00032	0.017	0.037	a
Permethrin	µg/g dw	10.83	0.00081	0.088	0.008	b
			Sum of TU Equivalents		0.516	a
Other MRP Pesticides of Concern						
Carbaryl	mg/Kg dw	NA	0.01	NA	NA	c
Fipronil	ng/g dw	410	<0.53	27.72	0.068	a
Fipronil Desulfinyl	ng/g dw	NA	<0.53	NA	NA	c
Fipronil Sulfide	ng/g dw	NA	<0.53	NA	NA	c
Fipronil Sulfone	ng/g dw	NA	<0.53	NA	NA	c

a. Concentration was below the method detection limit (MDL). TOC normalized concentrations and TU equivalents calculated using 1/2 MDL.

b. TU equivalents calculated from concentration below the reporting limit (J-flagged).

c. Currently there is no available LC50 value for Carbaryl or Fipronil degradates, however the observed concentrations were below the detection limits.

d. Sources: Amweg et al. 2005 and Maund et al. 2002.

In compliance with the MRP, a grain size analysis was conducted on the sediment sample (Table 6.6). The sample was 10.7% fines (i.e., 3.4% clay and 7.4% silt).

Table 6.6. Summary of grain size for site 202SPE005 in San Mateo County during WY 2018.

Grain Size (%)		204COR010 Cordilleras Creek
Clay	<0.0039 mm	3.4%
Silt	0.0039 to <0.0625 mm	7.4%
Sand	V. Fine 0.0625 to <0.125 mm	4.7%
	Fine 0.125 to <0.25 mm	13.4%
	Medium 0.25 to <0.5 mm	26.7%
	Coarse 0.5 to <1.0 mm	27.4%
	V. Coarse 1.0 to <2.0 mm	17.0%
Granule	2.0 to <4.0 mm	10.6%
Pebble	Small 4 to <8 mm	13.1%
	Medium 8 to <16 mm	0%
	Large 16 to <32 mm	0%
	V. Large 32 to <64 mm	0%

Note: Sum of grain size values for both sites is greater than 100% due to the laboratory analytical methods used.

5.3.3 Pesticides in Water

The pesticide concentrations measured at the two sites where wet weather pesticide sampling was conducted in WY 2018 are listed in Table 6.7. The concentrations of most pesticides were below the MDL, meaning that these analytes were reported as non-detects. Imidacloprid was found at detectable levels at one of the two sites (Cordilleras Creek). Additionally, fipronil and its degradation products were found at detectable levels at both sites.

Table 6.7. Summary of wet weather pesticide concentrations for the two locations sampled in San Mateo County during WY 2018.

	Unit	202SPE005 San Pedro Creek	204COR010 Cordilleras Creek	Lowest USEPA Benchmark [a]	
		Concentration	Concentration	Concentration	
Pyrethroid					
Bifenthrin	µg/L	<0.00005 [b]	<0.00005 [b]	0.0013	IC
Cyfluthrin	µg/L	<0.00005 [b]	<0.00005 [b]	0.0074	IC
Cypermethrin	µg/L	<0.00005 [b]	<0.00005 [b]	0.069	IC
Deltamethrin	µg/L	<0.00005 [b]	<0.00005 [b]	0.0041	IC
Esfenvalerate	µg/L	<0.00005 [b]	<0.00005 [b]	0.017	IC
Fenvalerate	µg/L	<0.00005 [b]	<0.00005 [b]	0.017	IC
Lambda-Cyhalothrin	µg/L	<0.00005 [b]	<0.00005 [b]	0.002	IC
Permethrin, cis-	µg/L	<0.0002 [b]	<0.0002 [b]	0.0014	IC
Permethrin, trans-	µg/L	<0.0001 [b]	<0.0001 [b]	0.0014	IC
Other MRP Pesticides of Concern					
Fipronil	µg/L	0.0658	0.0523	0.011	IC
Fipronil Desulfinyl	µg/L	0.0032	0.0038	0.54	FC
Fipronil Sulfide	µg/L	0.0029	0.0032	0.11	IC
Fipronil Sulfone	µg/L	0.0156	0.0145	0.037	IC
Imidacloprid	µg/L	<0.002 [b]	0.0659	0.01	IC

a. Source: USEPA Aquatic Life Benchmarks and Ecological Risk Assessments for Registered Pesticides. IC signifies that the invertebrate chronic USEPA benchmark was the lowest benchmark, while FC signifies that the fish chronic USEPA benchmark was the lowest benchmark.

b. Concentration was below the method detection limit (MDL), and values are displayed as “<MDL”.

As previously stated, there are no water quality objectives specified in the San Francisco Bay Basin Plan for water column pesticide analytes. As a result, no analysis of the wet weather pesticide monitoring data collected in WY 2018 relative to WQOs could be performed. However, other studies that quantify pesticide concentrations in water can provide a perspective with which to view the results of the MRP WY 2018 wet weather pesticide monitoring. DPR routinely conducts pesticide monitoring at MS4 and receiving water sites in both Northern and Southern California with the objectives of evaluating pesticide concentrations in water, frequencies with which individual pesticide compounds are detected, and exceedances of USEPA pesticide benchmarks. In WY 2017, DPR monitored locations in Alameda, Contra Costa, Placer, Sacramento, and Santa Clara Counties in Northern California as well as locations in Los Angeles, Orange, and San Diego Counties in Southern California. The pesticide analytes sampled in both studies encompassed the analytes sampled by the MRP wet weather pesticide monitoring.

In the Northern California DPR study, bifenthrin had a detection frequency (DF) of 74%, making it the most frequently detected insecticide. Other pyrethroids sampled during the study were either not detected at all or had significantly lower DF values than bifenthrin. Imidacloprid was the second-most frequently detected insecticide with a DF of 59%. Fipronil, with a DF of 50%, closely followed imidacloprid as the third-most frequently detected insecticide. Fipronil desulfinyl and fipronil sulfone were also detected at rates of 56% and 21%, respectively. Pyrethroid concentrations were generally above their USEPA minimum benchmarks for toxicity to aquatic life with the exception of cyfluthrin, which is generally detected below the USEPA toxicity benchmark. Concentrations of imidacloprid and fipronil were always above their minimum benchmarks when detected by the DPR SWPP. The fipronil degradates were not above their minimum benchmarks except for one fipronil sulfone sample. (Ensminger 2017)

In the Southern California DPR study, bifenthrin was the most frequently detected pyrethroid insecticide with a DF of 79%. The other sampled pyrethroids were again either not detected at all or detected significantly less frequently than bifenthrin. Fipronil also had a DF of 79%, and several of its degradates including fipronil sulfone and fipronil desulfinyl were also detected at comparably high concentrations (72 and 70%, respectively). Imidacloprid was the most frequently detected pesticide at a rate of 81%. (Budd 2018)

The results of the MRP wet weather pesticide monitoring in WY 2018 are similar to the WY 2017 DPR studies with respect to fipronil, fipronil degradates, and imidacloprid results, as these compounds were the only pesticides detected during the MRP monitoring. Additionally, the concentrations of MRP samples for fipronil and imidacloprid were above their USEPA minimum benchmarks. Although bifenthrin was frequently detected during the DPR studies, and it is known to be the leading cause of toxicity in urban watersheds (Ruby 2013), bifenthrin was not detected during the MRP wet weather monitoring in San Pedro Creek and Cordilleras Creek.

7.0 Conclusions and Recommendations

In WY 2018, in compliance with Provisions C.8.d and C.8.g of the MRP and the BASMAA RMC Creek Status and Long-Term Trends Monitoring Plan (BASMAA 2012), SMCWPPP continued to implement a two-component monitoring design that was initiated in WY 2012. The strategy includes a regional ambient/"probabilistic" bioassessment monitoring component and a component based on local "targeted" monitoring for general water quality parameters and pesticides/toxicity. The combination of these monitoring designs allows each individual RMC participating program to assess the status of Beneficial Uses in local creeks within its Program (jurisdictional) area, while also contributing data to eventually answer management questions at the regional scale (e.g., differences between aquatic life condition in urban and non-urban creeks).

Conclusions from the MRP Creek Status and Pesticides/Toxicity Monitoring conducted during WY 2018 in San Mateo County are based on the management questions presented in Section 1.0 of this report:

1) *Are water quality objectives, both numeric and narrative, being met in local receiving waters, including creeks, rivers, and tributaries?*
2) *Are conditions in local receiving water supportive of or likely supportive of beneficial uses?*

The first management question is addressed primarily through the evaluation of probabilistic and targeted monitoring data with respect to the triggers defined in the MRP. A summary of trigger exceedances observed for each site is presented in Table 7.1. Sites where triggers are exceeded may indicate potential impacts to aquatic life or other beneficial uses and are considered for future evaluation of Stressor/Source identification (SSID) projects.

The second management question is addressed primarily by assessing indicators of aquatic biological health using benthic macroinvertebrate and algae data collected at probabilistic sites. The indices of biological integrity based on BMI and algae data (i.e., CSCI and ASCI) are direct measures of aquatic life beneficial uses. Biological condition scores were compared to physical habitat and water quality data collected synoptically with bioassessments to evaluate whether any correlations exist that may explain the variation in biological condition scores. Continuous monitoring data (temperature, dissolved oxygen, pH, and specific conductance) are evaluated with respect to COLD and WARM Beneficial Uses. And pathogen indicator data are used to assess REC-1 (water contact recreation) Beneficial Uses.

7.1 Conclusions

7.1.1 Biological Condition Assessment

Bioassessment monitoring was conducted in compliance with Provision C.8.d.i of the MRP. In WY 2018, all bioassessment monitoring was performed at sites selected randomly using the regional probabilistic monitoring design. The probabilistic monitoring design allows each individual RMC participating program to objectively assess stream ecosystem conditions within its program area (e.g., County boundary) while contributing data to answer regional management questions about water quality and beneficial use condition in San Francisco Bay Area creeks. The monitoring design was developed to address the following management questions:

1. *What is the condition of aquatic life in creeks in the RMC area; are water quality objectives met and are beneficial uses supported?*
2. *What are major stressors to aquatic life in the RMC area?*
3. *What are the long-term trends in water quality in creeks over time?*

The first question (i.e., *What is the condition of aquatic life in creeks in the RMC area?*) is addressed by assessing indicators of aquatic biological health at probabilistic sampling locations. Once a sufficient number of samples have been collected (i.e., 30 samples), ambient biological condition can be estimated for streams at countywide and a regional scale within known estimates of precision. Over the past seven years (WY 2012 through WY 2018), SMCWPPP and Regional Water Board have sampled 80 probabilistic sites in San Mateo County, providing a sufficient sample size to estimate ambient biological condition for urban streams countywide. Analysis of the first five years of regional bioassessment monitoring data (WY 2012 – WY 2016) was conducted by BASMAA in the RMC 5-Year Report.

The second question (i.e., *What are major stressors to aquatic life in the RMC area?*) is addressed by the collection and evaluation of physical habitat and water chemistry data collected at the probabilistic sites, as potential stressors to biological health. The stressor levels can be compared to biological indicator data through correlation and relative risk analyses. Assessing the extent and relative risk of stressors can help prioritize stressors at a regional scale and inform local management decisions.

The third question (i.e., *What are the long-term trends in water quality in creeks over time?*) is addressed by assessing the change in biological condition over several years. Changes in biological condition over time can help evaluate the effectiveness of management actions. Based on review of the first five years of probabilistic data, it appears that long-term trend analysis for the probabilistic survey will require more than seven years of data.

The analyses presented in this report are limited to the WY 2018 dataset which does not contain a statistically significant number of records (i.e., approximately 30 samples). A more comprehensive analysis of the much larger bioassessment dataset from the first five years of MRP monitoring (WY 2012 – WY 2016) was conducted by the BASMAA RMC on a regional and countywide basis. The RMC 5-Year Report is summarized below and included with this report as Attachment 2. Analytical tools that BASMAA (2019) found to be useful in evaluating stressor association with biological condition (i.e., random forest models) may be used by SMCWPPP to evaluate the WY 2012 – WY 2019 dataset in the Integrated Monitoring Report which will be submitted in March 2020.

Bioassessment Data (San Mateo County – WY 2018)

Ten sites were sampled for benthic macroinvertebrates, benthic algae, and nutrients. Physical habitat was also assessed at each of the 10 stations, and general water quality parameters were measured using a pre-calibrated multi-parameter field probe. All of this work was conducted using methods consistent with the BASMAA RMC QAPP (BASMAA 2016a) and SOPs (BASMAA 2016b). Stations were randomly selected using a probabilistic monitoring design. Eight of the ten sites (80%) were classified as urban and two (20%) were classified and non-urban.

The following conclusions are based on the WY 2018 data. An assessment of biological condition is provided, relationships with potential stressors are explores, and potential stressors are compared to applicable WQOs and triggers identified in the MRP. Sites with monitoring results that exceed WQOs and triggers are considered as candidates for further investigation as SSID projects, consistent with Provision C.8.e of the MRP.

<u>Biological Condition Assessment</u>

Stream condition was assessed using three different types of indices/tools: the BMI-based CSCI, the draft benthic algae-based ASCI (diatom, soft algae, and hybrid), and the physical habitat-based IPI. Of these three, the CSCI is the only tool with a MRP trigger threshold for follow-up SSID consideration.

- **CSCI** - The diversity and abundance of BMI taxa are evaluated as indicators of biological condition of the stream. Five of the ten (50%) sites monitored in WY 2018 had CSCI scores in the two higher condition categories: “possibly intact” and “likely intact”. These higher scoring sites were relatively undeveloped, with imperviousness in their drainage areas ranging between 1% and 5%.
  - The five sites with CSCI scores below the MRP trigger threshold of 0.795 will be considered as candidates for SSID projects.
- **ASCI -** ASCI indices translate benthic algae data (diatoms and soft algae) into overall measures of stream health. Three algae indices (developed using statewide data) were calculated for diatoms, soft algae and hybrid (combination of diatoms and soft algae). The hybrid ASCI appeared to have the best response to stressor data associated with landscape variables (e.g., percent imperviousness), but not with stressors associated with nutrients, which was a finding from statewide data analyses (Theroux et al (in prep)).
  - **Hybrid**. Seven of the ten (70%) bioassessment sites had hybrid ASCI scores that were classified as “possibly intact” or “likely intact” condition. The higher scoring sites occurred primarily in drainages with low levels of urbanization, ranging from 1% to 7% impervious area, with the exception of site 202R03404 in San Pedro Creek (13%). Five of the seven sites also received CSCI scores that were in two higher condition categories
- **IPI –** The Index for Physical Habitat Integrity assesses the overall habitat condition of the sampling reach. IPI scores were positively correlated with qualitative habitat assessment Total PHAB scores.
  - Seven of the ten sites (70%) had IPI scores in the two upper condition categories. IPI scores were positively correlated with CSCI scores, and slightly less so with hybrid ASCI scores.
- **Overall Condition -** There were four sites with biological condition scores in the two higher condition categories all three indices (CSCI, hybrid ASCI, IPI) (Figure 2.6). Two of the sites are located in Mid-Peninsula Open Space District land, including La Honda Creek Preserve (site 202R03880) and Windy Hill Preserve (site 205R03864). The third site is located in Pescadero Creek County Park (site 202R00614). The fourth site was on Bear Creek, near the urban boundary of the Town of Woodside (site 205R03624). All four sites were relatively undeveloped (less than < 5% impervious area).

The number of sites in the top two condition categories varied substantially by index, with as many as 9 of 10 sites for the diatom ASCI to as few as 5 of 10 sites for the CSCI and 4 of 8 sites for the soft algae ASCI. Excluding the soft algae ASCI, there was relatively good consistency among the indices in terms of which sites were placed in the top two condition categories for sites with lower urbanization (< 5% impervious area). However, all three ASCI indices and the IPI were relatively variable (i.e., both high and low scoring) at the more developed sites. Further evaluation of the newer indices and their association with stressor data is needed to better understand how these indicators can be used to effectively assess site conditions.

Stressor Assessment

Relationships between potential stressors (water chemistry, physical habitat, and landscape variables such as imperviousness) and biological condition were explored using the WY 2018 dataset. Correlations were evaluated using simple regression models and are not expected to be very strong due to small sample size. Sites with stressor levels exceeding applicable WQOs and triggers identified in the MRP will be considered as candidates for SSID projects.

- **General water quality** - pH, temperature, dissolved oxygen, specific conductance. None of the water quality measurements exceeded water quality objectives or MRP trigger thresholds. None of the water quality measurements were correlated with CSCI or hybrid ASCI scores.

- **Nutrients and conventional analytes** - ammonia, unionized ammonia, chloride, Ash-Free Dry Mass (AFDM), chlorophyll a, nitrate, nitrite, TKN, ortho-phosphate, phosphorus, silica. There were no water quality objective exceedances for the water chemistry parameters (unionized ammonia, nitrate, chloride). Total nitrogen concentrations ranged from 0.22 to 1.1 mg/L. Total phosphorus concentrations ranged from <0.01 to 0.12 mg/L. None of the nutrient parameters were correlated with CSCI or hybrid ASCI scores.

- **Physical habitat metric scores** were generated from the physical habitat data. CSCI scores were positively correlated with flow type and negatively correlated with filamentous algae cover. Hybrid ASCI scores were poorly correlated with all 11 physical habitat metrics.

- **Landscape variables** were calculated for each of the watershed areas draining into the bioassessment sites. CSCI scores were moderately correlated (negatively) with impervious area and road density.

Regional Bioassessment Data (WY 2012 – WY 2016)

A comprehensive analysis of bioassessment data collected by the RMC partners throughout the Bay area is included in the RMC Five-Year Bioassessment Report (5-Year Report) (BASMAA 2019) (Attachment 2). The BASMAA-funded study evaluated bioassessment data collected throughout the Bay Area by the RMC over the first five years of monitoring (WY 2012 – WY 2016). Bioassessment data from 354 sites were compiled and evaluated to address the three study questions:

1) What is the biological condition of streams in the region?
2) What stressors are associated with poor condition?
3) Are conditions changing over time?

The findings of the BASMAA study are intended to help stormwater programs better understand the current condition of wadable streams, prioritize stream reaches in need of protection or restoration, and identify stressors that are likely to pose the greatest risk to the health of streams in the Bay Area.

The BASMAA report also evaluated the existing RMC probabilistic monitoring design and identified a range of potential options for revising the design (if desired) to better address the questions posed. These redesign options are intended to inform discussions of water quality monitoring requirements during the reissuance of the Municipal Regional Permit, which expires at the end of 2020.

Biological Condition Assessment

Results of the survey indicate that much of the stream length in the RMC area is in poor biological condition. Aquatic life uses may not be fully supported at a majority of sites sampled by the RMC. Two biological indicators were used to assess conditions:

- The BMI-based CSCI shows that 58% of the stream length region-wide was ranked in the lowest CSCI condition category ("very likely altered"), and 74% of the sampled stream length exhibited CSCI scores below 0.795, the MRP trigger for potential follow-up activity.
- The Southern California algae indices for diatoms (D18) and soft algae (S2) were evaluated for biological conditions[26]. Based on D18 and S2 scores, stream conditions region-wide appear somewhat less degraded than the CSCI scores indicated, with approximately 40% ranked in the lowest algae condition category. The algal indices also had greater stream length in the "likely intact" condition class (19-21%) compared to CSCI score (15%).

These findings should be interpreted with the understanding that the survey focused on urban stream conditions. Approximately 80% of the samples (284 of 354) were collected at urban sites. Although the low non-urban sample size precludes making any definitive comparisons, bioassessment scores in the non-urban area were generally higher than scores in the urban area for each County.

Stressor Assessment

The association between biological indicators (CSCI and D18) and stressor data was evaluated in the RMC 5-Year study using random forest statistical analyses. The results indicate that each of the biological indicators respond to different types of stressors.

- Biological condition, based on CSCI scores, was correlated with physical habitat and land use variables. Overall, the largest influence on CSCI scores in the random forest model was percent impervious area in catchment area within a 5 km radius of the bioassessment sampling site.

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[26] The ASCI was not yet available during development of the RMC 5-Year Report.

- Biological condition, based on D18 scores, was moderately correlated with water quality variables and poorly correlated with the physical or landscape variables.

In general, CSCI scores at urban sites were consistently low, indicating that degraded physical habitat conditions do not support healthy BMI assemblages. D18 scores at urban sites were more variable, indicating that healthy diatom assemblages potentially can occur at sites with poor habitat.

None of the nutrient variables (e.g., nitrate, total nitrogen, orthophosphate, phosphorus) correlated strongly with CSCI scores, or were highly ranked variables in the CSCI random forest analysis. Phosphorus and ash-free dry mass (which increases in response to biostimulation) were important in predicting D18 scores based on the random forest analysis; however, no statistically significant relationships were observed. This finding suggests that the nutrient targets being developed by the State Water Board as part of the Biostimulatory/Biointegrity Project may not be appropriate in urban streams in the Bay Area.

Trend Assessment

The time frame of the survey (five years) is too short to detect trends. However, the five-year bioassessment dataset does provide a baseline to compare with future assessments.

A potential application of bioassessment monitoring may be to assess trends in stream conditions as additional stormwater treatment (e.g., green infrastructure) and creek restoration projects are implemented across the urban landscape over time. Peak flow volumes and intensities will likely be reduced following the implementation of stormwater treatment via green infrastructure and low impact development (LID), as required by the MRP. Future creek status monitoring may provide additional insight into the potential positive impacts of green infrastructure and creek restoration to support WQOs and beneficial uses in urban creeks.

Assessment of the RMC Monitoring Design

Over the first five years of monitoring, the RMC evaluated about 25% (1455 out of 5740) of the sites in the sample frame to obtain 354 samples. Approximately 46% (873 out of 1896) of the total number of urban sites in the sample frame were evaluated during that time. Based on rejection rates from previous years, the sample frame is anticipated to be exhausted during WY 2020. Revision of the RMC monitoring design could seek to reduce the future rejection rate through development of a new sample frame that excludes areas of low management interest or regions that would not be candidates for sampling (such as due to lack of permissions or physical barriers to access). This would improve the spatial balance of samples that more closely represents the proportion of the sample frame that can be reliably assessed.

The RMC sample design was created to probabilistically sample all streams within the RMC area, which resulted in a master list with 33% urban sites and 67% non-urban sites. However, because participating municipalities are primarily concerned with runoff from urban areas, the RMC focused sampling efforts on urban sites (80%) over non-urban sites (20%). As a result, non-urban samples are under-represented in the dataset resulting in much lower overall biological condition scores than would be expected for a spatially balanced dataset.

Based on evaluation of data collected during the first five years of the survey, there are several options to revise the RMC Monitoring Design.

The RMC will assess the options during discussions with Regional Water Board staff during the MRP reissuance process beginning in 2019.

7.1.2 Continuous Monitoring for Temperature and General Water Quality

Continuous monitoring of water temperature and general water quality in WY 2018 was conducted in compliance with Provisions C.8.d.iii – iv of the MRP. Hourly temperature measurements were recorded at five sites in the San Pedro Creek watershed from April through September. Continuous (15-minute) general water quality measurements (pH, DO, specific conductance, temperature) were recorded at two sites in the San Pedro Creek watershed during two 2-week periods in May (Event 1) and August (Event 2). Targeted monitoring stations were deliberately selected and were the same as those monitored in WY 2017.

Conclusions from targeted continuous monitoring in WY 2018 are organized on the basis of the management questions listed in Section 3.0:

1. *What is the spatial and temporal variability in water quality conditions during the spring and summer season?*
2. *Do general water quality measurements indicate potential impacts to aquatic life?*

Sites with targeted monitoring results exceeding the MRP trigger criteria and/or WQOs are identified as candidate SSID projects.

Spatial and Temporal Variability of Water Quality Conditions

- **Spatial**. There was minimal spatial variability in water temperature across the five stations in the San Pedro Creek watershed. Temperature increased slightly at each downstream site but remained 4 to 7 °C below the MRP instantaneous maximum trigger threshold. Likewise, pH and specific conductivity increased slightly in the downstream direction and dissolved oxygen decreased slightly in the downstream direction.
- **Temporal**. Water temperature increased gradually at all five stations between April and early-September, likely in response to periods of warmer air temperatures. Differences in general water quality measurements (pH, specific conductivity, dissolved oxygen) between the two two-week monitoring periods (May/June and August/September) were less pronounced. WY 2018 monitoring results were very similar to those recorded in WY 2017 at the same stations.

Potential Impacts to Aquatic Life

- Potential impacts to aquatic life were assessed through analysis of continuous temperature data collected at five targeted stations and continuous general water quality data (pH, dissolved oxygen, specific conductance, and temperature) collected at two targeted stations in San Pedro Creek. San Pedro Creek, located in the City of Pacifica, was targeted for temperature and general water quality monitoring because it contains the northern-most population of naturally producing steelhead trout (*Oncorhynchus mykiss*) in San Mateo County.
- None of the temperature stations in San Pedro Creek exceeded the MRP trigger threshold for the Maximum Weekly Average Temperature of 17°C. None of the stations exceeded the MRP instantaneous maximum trigger threshold of 24°C.

- None of the general water quality parameters (temperature, pH, dissolved oxygen, and specific conductance) exceeded any of the MRP trigger thresholds.

7.1.3 Pathogen Indicators

Pathogen indicator monitoring in WY 2018 was conducted in compliance with Provision C.8.d.v of the MRP. Pathogen indicator grab samples were collected at five sites in the Pescadero Creek watershed during a sampling event on July 27, 2018.

- The selection of sites was based on information provided by County Parks staff about high bacteria concentrations previously found in creeks within Memorial County Park. All three creeks sampled by SMCWPPP in WY 2018 are designated for both contact (REC-1) and non-contact (REC-2) recreation Beneficial Uses and several swimming holes are located along Pescadero Creek in and around Memorial County Park.

- The MRP trigger threshold for *E. coli* was not exceeded at any site in WY 2018; however, the MRP trigger threshold for enterococci was exceeded at two sites. These sites will be added to the list of candidate SSID projects.

- Pathogen indicator data should be interpreted cautiously due to the high variability found in creeks. In addition, wildlife sources in the WY 2018 monitoring area may contribute to the elevated concentrations of pathogen indicators in the creek but pose very little human health risk to recreators, relative to human sources of fecal contamination.

7.1.4 Chlorine Monitoring

Free chlorine and total chlorine residual were measured concurrently with bioassessments at the ten probabilistic sites in compliance with Provision C.8.c.ii. While chlorine residual has generally not been a concern in San Mateo County creeks, prior monitoring results suggest there are occasional trigger exceedances of free chlorine and total chlorine residual in the County. Trigger exceedances may be the result of one-time potable water discharges, and it is generally challenging to determine the source of elevated chlorine from such episodic discharges. Furthermore, chlorine in surface waters can dissipate from volatilization and reaction with dirt and organic matter. In WY 2018, there were no exceedances of the MRP trigger for chlorine (0.1 mg/L). SMCWPPP will continue to monitor chlorine in compliance with the MRP and, as in the past, will follow-up with municipal illicit discharge staff as needed.

7.1.5 Pesticides and Toxicity Monitoring

In WY 2018, SMCWPPP conducted dry weather pesticides and toxicity monitoring at one station (Cordilleras Creek) and wet weather pesticides and toxicity monitoring at two stations (Cordilleras Creek and San Pedro Creek) in compliance with Provision C.8.g of the MRP.

During the dry season, statistically significant toxicity to *C. dubia* was observed in the water sample collected from Cordilleras Creek. During wet weather monitoring, statistically significant toxicity to *H. azteca* was observed in the water samples collected from both creeks during the and toxicity to *P. promelas* was observed in the water sample collected from San Pedro Creek. However, the magnitude of the toxic effects in the samples compared to laboratory controls did not exceed MRP trigger criteria of 50 Percent Effect. The cause of the observed toxicity is unknown. Pesticide concentrations in the sediment sample were all very low, most below the MDL, and TU equivalents, with the exception of bifenthrin, did not exceed 0.1. Likewise, all pesticides (except fipronil and its degradates) analyzed in the wet weather samples were below the MDL

Sediment chemistry results are evaluated to identify potential stressors based on TEC quotients and PEC quotients according to criteria in Provision C.8.g.iv of the MRP. SMCWPPP also evaluated TU equivalents of pyrethroids and fipronil. TEC and PEC quotients were calculated for all metals and total PAHs measured in the sediment samples. Two TEC quotients exceeded the MRP threshold of 1.0 (chromium and nickel), but no PEC quotients exceeded the threshold. Decisions about which SSID projects to pursue should be informed by the fact that the TEC and PEC quotient exceedances are likely related to naturally occurring chromium and nickel due to serpentine soils in local watersheds. Except for bifenthrin (with a TU equivalent of 0.251), all of the calculated TU equivalents were less than 0.1. Bifenthrin is considered to be the leading cause of pyrethroid-related toxicity in urban areas (Ruby 2013) and the most-commonly detected insecticide monitored by the California DPR SWPP (Ensminger 2017).

Pesticide analytes targeted by wet weather monitoring in WY 2018 were generally found at concentrations below the MDL, except for bifenthrin and fipronil compounds. As no WQOs are specified in the Basin Plan for these pollutants (SFRWQCB 2017), they are not currently being used to identify SSID project locations. The wet weather pesticide monitoring data in WY 2018 were compared to pesticide data collected by the DPR SWPP and the USEPA aquatic benchmarks used in DPR SWPP studies to allow for interpretation of the WY 2018 results in the context of larger statewide datasets. However, sites sampled during the WY 2018 wet weather pesticide monitoring where exceedances of the USEPA benchmarks were observed were not added to the list of candidate SSID projects. In future years, data collected by the DPR SWPP and contained on the DPR SURF database can be queried to allow for comparison of MRP pesticide monitoring results.

7.2 Trigger Assessment

The MRP requires analysis of the monitoring data to identify candidate sites for SSID projects. Trigger thresholds against which to compare the data are provided for most monitoring parameters in the MRP and are described in the foregoing sections of this report. Stream condition was assessed based on CSCI scores that were calculated using BMI data. Nutrient data were evaluated using applicable water quality standards from the Basin Plan (SFRWQCB 2017). Water and sediment chemistry and toxicity data were evaluated using numeric trigger thresholds specified in the MRP. In compliance with Provision C.8.e.i of the MRP, all monitoring results exceeding trigger thresholds are added to a list of candidate SSID projects that will be maintained throughout the permit term. Followup SSID projects will be selected from this list. Table 7.1 lists of candidate SSID projects based on WY 2017 Creek Status and Pesticides/Toxicity monitoring data.

Additional analysis of the data is provided in the foregoing sections of this report and should be considered prior to selecting and defining SSID projects. The analyses include review of physical habitat and water chemistry data to identify potential stressors that may be contributing to degraded or diminished biological conditions. Analyses in this report also include historical and spatial perspectives that help provide context and deeper understanding of the trigger exceedances.

Table 7.1. Summary of SMCWPPP MRP trigger threshold exceedance analysis, WY 2018. “No” indicates samples were collected but did not exceed the MRP trigger; “Yes” indicates an exceedance of the MRP trigger.

Station Number	Creek Name	Bioassessment [1]	Nutrients [2]	Chlorine [3]	Water Toxicity [4]	Water Chemistry [5]	Sediment Toxicity [4]	Sediment Chemistry [5]	Continuous Temperature [6]	Dissolved Oxygen [7]	pH [8]	Specific Conductance [9]	Pathogen Indicators [10]
202R00584	Pilarcitos Creek	No	No	No	--	--	--	--	--	--	--	--	--
202R00614	Pescadero Creek	No	No	No	--	--	--	--	--	--	--	--	--
202R03404	San Pedro Creek	Yes	No	No	--	--	--	--	--	--	--	--	--
202R03656	Pilarcitos Creek	Yes	No	No	--	--	--	--	--	--	--	--	--
202R03880	La Honda Creek	No	No	No	--	--	--	--	--	--	--	--	--
202R03916	San Pedro Creek	Yes	No	No	--	--	--	--	--	--	--	--	--
204R03508	Mills Creek	Yes	No	No	--	--	--	--	--	--	--	--	--
204R03528	San Mateo Creek	Yes	No	No	--	--	--	--	--	--	--	--	--
205R03624	Bear Creek	No	No	No	--	--	--	--	--	--	--	--	--
205R03864	Hamms Gulch	No	No	No	--	--	--	--	--	--	--	--	--
202SPE005	San Pedro Creek	--	--	--	No	No	--	--	--	--	--	--	--
204COR010	Cordilleras Creek	--	--	--	No	No	No	Yes	--	--	--	--	--
202PES138	Pescadero Creek	--	--	--	--	--	--	--	--	--	--	--	Yes
202PES142	McCormick Creek	--	--	--	--	--	--	--	--	--	--	--	Yes
202PES144	Pescadero Creek	--	--	--	--	--	--	--	--	--	--	--	No
202PES150	Jones Gulch	--	--	--	--	--	--	--	--	--	--	--	No
202PES154	Pescadero Creek	--	--	--	--	--	--	--	--	--	--	--	No
202SPE019	San Pedro Creek	--	--	--	--	--	--	--	No	--	--	--	--
202SPE040	San Pedro Creek	--	--	--	--	--	--	--	No	No	No	No	--
202SPE050	San Pedro Creek	--	--	--	--	--	--	--	No	--	--	--	--
202SPE070	San Pedro Creek	--	--	--	--	--	--	--	No	No	No	No	--
202SPE085	San Pedro Creek	--	--	--	--	--	--	--	No	--	--	--	--

1. CSCI score ≤ 0.795.
2. Unionized ammonia (as N) ≥ 0.025 mg/L, nitrate (as N) ≥ 10 mg/L, chloride > 250 mg/L.
3. Free chlorine or total chlorine residual ≥ 0.1 mg/L.
4. Test of Significant Toxicity = Fail and Percent Effect ≥ 50 %.
5. TEC or PEC quotient ≥ 1.0 for any constituent.
6. Two or more MWAT ≥ 17.0°C or 20% of results ≥ 24°C.
7. DO < 7.0 mg/L in COLD streams or DO < 5.0 mg/L in WARM streams.
8. pH < 6.5 or pH > 8.5.
9. Specific conductance > 2000 uS.
10. Enterococcus ≥ 130 cfu/100ml or *E. coli* ≥ 410 cfu/100ml.

7.3 Recommendations

The following recommendations are based on findings from WY 2018 Creek Status and Pesticides and Toxicity monitoring conducted by SMCWPPP, as well as reflections on other monitoring, data analysis, and policy development projects being conducted in the region (e.g., RMC 5-Year Report) and statewide.

- In WY 2019, SMCWPPP will continue to coordinate with RMC partners on implementation of monitoring requirements in MRP Provisions C.8.d and C.8.g.
- A major component of the WY 2019 monitoring will be bioassessment surveys and data assessment. In WY 2019, SMCWPPP will conduct biological assessments at both probabilistic and targeted sites. To date, a total of 80 probabilistic sites have been monitored by SMCWPPP (n=7) and SWAMP (n=10). This exceeds the number of samples necessary for a statistically representative dataset. Therefore, SMCWPPP is has the option to select up to 20 percent of sample locations on a targeted basis to evaluate trends or address other aquatic life related concerns.
- In WY 2018, BASMAA funded a study to evaluate five years of regional bioassessment data (WY 2012 – WY 2016). Findings from the RMC 5-Year Report are summarized in Section 7.1.1 and the report is included as Attachment 2. In WY 2019, SMCWPPP will apply some of the tools used in the RMC 5-Year Report (i.e., random forest models) to analyze bioassessment data collected in San Mateo County over all eight years of MRP monitoring (WY 2012 – WY 2019). Results of the analyses will be described in the Integrated Monitoring Report (IMR) which will be developed following WY 2019 and must be submitted by March 31, 2020 (the fifth year of the Permit term) in lieu of an annual UCMR.
- For the past two years (WY 2017 and WY 2018), SMCWPPP has conducted continuous temperature and water quality monitoring in the San Pedro Creek Watershed. In WY 2019, SMCWPPP will work with San Mateo County MRP Permittees to select a different creek or reach to target, perhaps where targeted bioassessment monitoring sites are located.
- Provision C.8.g Pesticides and Toxicity monitoring will be conducted during the dry season at a bottom-of-the-watershed station. In order to expand the geographic extent of these data, a new station will be selected.

7.4 Management Implications

The Creek Status and Pesticides and Toxicity Monitoring programs (consistent with MRP Provisions C.8.d and C.8.g, respectively) focus on assessing the water quality condition of urban creeks in San Mateo County and identifying stressors and sources of impacts observed. The bioassessment station sample size from WY 2018 (overall n=10; urban n=8) was not sufficient to develop statistically representative conclusions regarding the overall condition of all creeks. A more comprehensive bioassessment data analyses for the entire eight years of monitoring under the MRP (WY 2012 through WY 2019) will be conducted as part of the Integrated Monitoring Report during WY 2019.

Like previous years, WY 2018 data suggest that most urban streams have likely or very likely altered populations of aquatic life indicators (e.g., benthic macroinvertebrates). These conditions are likely the result of long-term changes in stream hydrology, channel geomorphology, in-stream habitat complexity, and other modifications to the watershed and riparian areas associated with the urban development that has occurred over the past 50 plus years.

SMCWPPP Permittees are actively implementing many stormwater management programs to address these and other stressors and associated sources of water quality conditions observed in local creeks, with the goal of protecting these natural resources. For example:

- In compliance with MRP Provision C.3, new and redevelopment projects in the Bay Area are now designed to more effectively reduce water quality and hydromodification impacts associated with urban development. Low impact development (LID) methods, such as rainwater harvesting and use, infiltration and biotreatment are required as part of development and redevelopment projects. In addition, planning for and implementing green infrastructure projects in the public right-of-way (e.g., during street projects) is increasingly being incorporated into the municipal master planning process. All of these measures are expected to reduce the impacts of urbanization on stream health.
- In compliance with MRP Provision C.9, Permittees are implementing pesticide toxicity control programs that focus on source control and pollution prevention measures. The control measures include the implementation of integrated pest management (IPM) policies/ordinances, public education and outreach programs, pesticide disposal programs, supporting the adoption of formal State pesticide registration procedures, and sustainable landscaping requirements for new and redevelopment projects. These efforts should reduce pyrethroids and other pesticides in urban stormwater runoff and reduce the magnitude and extent of toxicity in local creeks.
- Trash loadings to local creeks have been reduced through implementation of new control measures in compliance with MRP Provision C.10 and other efforts by Permittees to reduce the impacts of illegal dumping directly into waterways. These actions include the installation and maintenance of trash capture systems, the adoption of ordinances to reduce the impacts of litter prone items, enhanced institutional controls such as street sweeping, and the on-going removal and control of direct dumping. The MRP establishes a mandatory trash load reduction schedule, minimum areas to be treated by full trash capture systems, and requires development of receiving water monitoring programs for trash.
- In compliance with MRP Provisions C.2 (Municipal Operations), C.4 (Industrial and Commercial Site Controls), C.5 (Illicit Discharge Detection and Elimination), and C.6 (Construction Site Controls) Permittees continue to implement Best Management Practices (BMPs) that are designed to prevent non-stormwater discharges during dry weather and reduce the exposure of stormwater runoff to contaminants during rainfall events.
- In compliance with MRP Provision C.13, copper in stormwater runoff is reduced through implementation of controls such as architectural and site design requirements, prohibition of discharges from water features treated with copper, and industrial facility inspections.
- Mercury and polychlorinated biphenyls (PCBs) in stormwater runoff are being reduced through implementation of the respective TMDL water quality restoration plans. In compliance with MRP Provisions C.11 (mercury) and C.12 (PCBs), the Countywide Program will continue to identify sources of these pollutants and will implement control actions designed to achieve load reduction goals. Monitoring activities conducted in WY

2018 that specifically target mercury and PCBs are described in the Pollutants of Concern Monitoring Data Report that is included as Appendix D to the WY 2018 UCMR.

In addition to controls implemented in compliance with the MRP, numerous other efforts and programs designed to improve the biological, physical and chemical condition of local creeks are underway. For example, C/CAG recently finalized the San Mateo Countywide Stormwater Resource Plan (SRP) to satisfy state requirements and guidelines to ensure C/CAG and San Mateo county MRP Permittees are eligible to compete for future voter-approved bond funds for stormwater or dry weather capture projects. The SRP identifies and prioritizes opportunities to better utilize stormwater as a resource in San Mateo County through a detailed analysis of watershed processes, surface and groundwater resources, input from stakeholders and the public, and analysis of multiple benefits that can be achieved through strategically planned stormwater management projects. These projects aim to capture and manage stormwater more sustainably, reduce flooding and pollution associated with runoff, improve biological functioning of plants, soils, and other natural infrastructure, and provide many community benefits, including cleaner air and water and enhanced aesthetic value of local streets and neighborhoods.

Through the continued implementation of MRP-associated and other watershed stewardship programs, SMCWPPP anticipates that stream conditions and water quality in local creeks will continue to improve overtime. In the near term, toxicity observed in creeks should decrease as pesticide regulations better incorporate water quality concerns during the pesticide registration process. In the longer term, control measures implemented to “green” the “grey” infrastructure and disconnect impervious areas constructed over the course of the past 50 plus years will take time to implement. Consequently, it may take several decades to observe the outcomes of these important, large-scale improvements to our watersheds in our local creeks. Long-term creek status monitoring programs designed to detect these changes over time are therefore beneficial to our collective understanding of the condition and health of our local waterways.

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ATTACHMENTS

Attachment 1

QA/QC Report

Quality Assurance/Quality Control Report

Prepared by:

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Prepared for:

San Mateo Countywide Water Pollution Prevention Program

March 31, 2018

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LIST OF ACRONYMS

BASMAA	Bay Area Stormwater Management Agencies Association
BMI	Benthic Macroinvertebrates
CDFW	California Department of Fish and Wildlife
DPD	Diethyl-p-phenylene Diamine
DQO	Data Quality Objective
EDDs	Electronic data deliverables
EV	Expected Value
KLI	Kinnetic Laboratories, Inc.
LCS	Laboratory Control Sample
LCSD	Laboratory Control Sample Duplicate
MPN	Most Probably Number
MQO	Measurement Quality Objective
MRP	Municipal Regional Permit
MS	Matrix Spike
MSD	Matrix Spike Duplicate
MV	Measured Value
ND	Non-detect
NIST	National Institute of Standards and Technology
NPDES	National Pollution Discharge Elimination System
NV	Native Value
PAH	Polycyclic Aromatic Hydrocarbon
PR	Percent Recovery
QA	Quality Assurance
QAPP	Quality Assurance Project Plan
QC	Quality Control
RL	Reporting Limit
RMC	Regional Monitoring Coalition
RPD	Relative Percent Difference
SAFIT	Southwest Association of Freshwater Invertebrate Taxonomists
SCCWRP	Southern California Coastal Water Research Project
SFRWQCB	San Francisco Regional Water Quality Control Board
SMCWPPP	San Mateo County Urban Pollution Prevention Program
SOP	Standard Operating Procedures
STE	Standard Taxonomic Effort
SV	Spike Value
SWAMP	Surface Water Ambient Monitoring Program
TKN	Total Kjeldahl Nitrogen
WY	Water Year

1. INTRODUCTION

In Water Year 2018 (WY 2018; October 1, 2017 through September 30, 2018), the San Mateo County Water Pollution Prevention Program (SMCWPPP) conducted Creek Status Monitoring in compliance with Provision C.8.d and Pesticide & Toxicity Monitoring in compliance with Provision C.8.g of the National Pollutant Discharge Elimination System (NPDES) stormwater permit for Bay Area municipalities referred to as the Municipal Regional Permit (MRP). The monitoring strategy includes regional ambient/probabilistic monitoring and local “targeted” monitoring as described in the Bay Area Stormwater Management Agencies Association (BASMAA) Regional Monitoring Coalition (RMC) Creek Status and Long-Term Trends Monitoring Plan (BASMAA 2012). SMCWPPP implemented a comprehensive data quality assurance and quality control (QA/QC) program, covering all aspects of the probabilistic and targeted monitoring. QA/QC for data collected was performed according to procedures detailed in the BASMAA RMC Quality Assurance Project Plan (QAPP) (BASMAA 2016a) and the BASMAA RMC Standard Operating Procedures (SOP; BASMAA 2016b), SOP FS-13 (Standard Operating Procedures for QA/QC Data Review). The BASMAA RMC QAPP and SOP are based on the QA program developed by the California Surface Water Ambient Monitoring Program (SWAMP; SCCWRP 2008).

Based on the QA/QC review, no WY 2018 data were rejected and some data were flagged. Overall, WY 2018 data met QA/QC objectives. Details are provided in the sections below.

1.1. DATA TYPES EVALUATED

During creek status monitoring, several data types were collected and evaluated for quality assurance and quality control. These data types include the following:

1. Bioassessment data
    a. Benthic Macroinvertebrates (BMI)
    b. Algae
2. Physical Habitat Assessment
3. Field Measurements
4. Water Chemistry
5. Pathogen Indicators
6. Continuous Water Quality (2-week deployment; 15-minute interval)
    a. Temperature
    b. Dissolved Oxygen
    c. Conductivity
    d. pH
7. Continuous Temperature Measurements (5-month deployment; 1-hour interval)

During pesticide & toxicity monitoring the following data types were collected and evaluated for quality assurance and quality control:

1. Water Toxicity (dry weather; MRP Provision C.8.g.i)
2. Sediment Toxicity (dry weather; MRP Provision C.8.g.ii)
3. Sediment Chemistry (dry weather; MRP Provision C.8.g.ii)
4. Water Pesticides (wet weather; MRP Provision C.8.giii)
5. Water Toxicity (wet weather; MRP Provision C.8.giii)

1.2. LABORATORIES

Laboratories that provided analytical and taxonomic identification support to SMCWPPP and the RMC were selected based on demonstrated capability to adhere to specified protocols. Laboratories are certified and are as follows:

- Caltest Analytical Laboratory (nutrients, chlorophyll a, ash free dry mass, sediment chemistry)
- Pacific EcoRisk, Inc. (water and sediment toxicity)

- Alpha Analytical Laboratories, Inc. (pathogen indicators)
- BioAsessment Services (benthic macroinvertebrate (BMI) identification)
- Jon Lee Consulting (BMI identification Quality Control)
- EcoAnalysts, Inc. (algae identification)
- Physis Environmental Laboratories, Inc. (water column pesticides)

1.3. QA/QC ATTRIBUTES

The RMC SOP and QAPP identify seven data quality attributes that are used to assess data QA/QC. They include (1) Representativeness, (2) Comparability, (3) Completeness, (4) Sensitivity, (5) Precision, (6) Accuracy, and (7) Contamination. These seven attributes are compared to Data Quality Objectives (DQOs), which were established to ensure that data collected are of adequate quality and sufficient for the intended uses. DQOs address both quantitative and qualitative assessment of the acceptability of data – representativeness and comparability are qualitative while completeness, sensitivity, precision, accuracy, and contamination are quantitative assessments.

Specific DQOs are based on Measurement Quality Objectives (MQOs) for each analyte. Chemical analysis relies on repeatable physical and chemical properties of target constituents to assess accuracy and precision. Biological data are quantified by experienced taxonomists relying on organism morphological features.

1.3.1. Representativeness

Data representativeness assesses whether the data were collected so as to represent actual conditions at each monitoring location. For this project, <u>all samples and field measurements are assumed to be representative</u> if they are performed according to protocols specified in the RMC QAPP and SOPs.

1.3.2. Comparability

The QA/QC officer ensures that the data may be reasonably compared to data from other programs producing similar types of data. For RMC Creek Status monitoring, individual stormwater programs try to maintain comparability within the RMC. The key measure of comparability for all RMC data is the California Surface Water Ambient Monitoring Program.

1.3.3. Completeness

Completeness is the degree to which all data were produced as planned; this covers both sample collection and analysis. For chemical data and field measurements an overall completeness of greater than <u>90%</u> is considered acceptable for RMC chemical data and field measurements. For bioassessment-related parameters – including BMI and algae taxonomy samples/analysis and associated field measurement – a completeness of <u>95%</u> is considered acceptable.

1.3.4. Sensitivity

Sensitivity analysis determines whether the methods can identify and/or quantify results at low enough levels. For the chemical analyses in this project, sensitivity is considered to be adequate if the reporting limits (RLs) comply with the specifications in RMC QAPP Appendix E: RMC Target Method Reporting Limits. For benthic macroinvertebrate data, taxonomic identification sensitivity is acceptable provided taxonomists use standard taxonomic effort (STE) Level I as established by the Southwest Association of Freshwater Invertebrate Taxonomists (SAFIT). There is no established level of sensitivity for algae taxonomic identification.

1.3.5. Accuracy

Accuracy is assessed as the percent recovery of samples spiked with a known amount of a specific chemical constituent. Chemistry laboratories routinely analyze a series of spiked samples; the results of these analyses are reported by the laboratories and evaluated using the RMC Database QA/QC Testing Tool. Acceptable levels of accuracy are specified for chemical analytes and toxicity test parameters in

RMC QAPP Appendix A: Measurement Quality Objectives for RMC Analytes, and for biological measurements in Appendix B: Benthic Macroinvertebrate MQOs and Data Production Process.

1.3.6. Precision

Precision is nominally assessed as the degree to which replicate measurements agree, nominally determined by calculation of the relative percent difference (RPD) between duplicate measurements. Chemistry laboratories routinely analyze a series of duplicate samples that are generated internally. The RMC QAPP also requires collection and analysis of field duplicate samples 5% of all samples for all parameters[1]. The results of the duplicate analyses are reported by the laboratories and evaluated using RMC Database QA/QC Testing Tool. Results of the Tool are confirmed manually. Acceptable levels of precision are specified for chemical analytes and toxicity test parameters in RMC QAPP Appendix A: Measurement Quality Objectives for RMC Analytes, and for biological measurements in Appendix B: Benthic Macroinvertebrate MQOs and Data Production Process.

1.3.7. Contamination

For chemical data, contamination is assessed as the presence of analytical constituents in blank samples. The RMC QAPP requires collection and analysis of field blank samples at a rate of 5% for orthophosphate.

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[1] The QAPP also requires the collection of field duplicate samples for 10% of biological samples (BMI and algae). However, there are no prescribed methods for assessing the precision of these duplicate samples.

2. METHODS

2.1. Representativeness

To ensure representativeness, each member of the SMCWPPP field crew received and reviewed all applicable SOPs and the QAPP. Most field crew members also attended a two-day bioassessment and field sampling training session from the California Water Boards Training Academy. The course was taught by California Department of Fish and Wildlife, Aquatic Bioassessment Laboratory staff and covered procedures for sampling benthic macroinvertebrates, algae, and measuring physical habitat characteristics using the applicable SWAMP SOPs. As a result, each field crew member was knowledgeable of, and performed data collection according to the protocols in the RMC QAPP and SOPs, ensuring that all samples and field measurements are representative of conditions in San Mateo County urban creeks.

2.2. Comparability

In addition to the bioassessment and field sampling training, SMCWPPP field crew members participated in an inter-calibration exercise with other stormwater programs prior to field assessments at least once during the permit term. During the inter-calibration exercise, the field crews also reviewed water chemistry (nutrient) sample collection and water quality field measurement methods. Close communication throughout the field season with other stormwater program field crews also ensured comparability.

Sub-contractors collecting samples and the laboratories performing analyses received copies of the RMC SOP and QAPP, and have acknowledged reviewing the documents. Data collection and analysis by these parties adhered to the RMC protocols and was included in their operating contracts.

Following completion of the field and laboratory work, the field data sheets and laboratory reports were reviewed by the SMCWPPP Program Quality Assurance staff, and were compared against the methods and protocols specified in the SOPs and QAPP. Specifically, staff checked for conformance with field and laboratory methods as specified in SOPs and QAPP, including sample collection and analytical methods, sample preservation, sample holding times, etc.

Electronic data deliverables (EDDs) were submitted to the San Francisco Regional Water Quality Control Board (SFRWQCB) in Microsoft Excel templates developed by SWAMP, to ensure data comparability with the SWAMP program. In addition, data entry followed SWAMP documentation specific to each data type, including the exclusion of qualitative values that do not appear on SWAMP's look up lists[2]. Completed templates were reviewed using SWAMP's online data checker[3], further ensuring SWAMP-comparability.

2.3. Completeness

2.3.1. Data Collection

All efforts were made to collect 100% of planned samples. Upon completion of all data collection, the number of samples collected for each data type was compared to the number of samples planned and the number required by the MRP, and reasons for any missed samples were identified. When possible, SMCWPPP staff resampled sites if missing data were identified prior to the close of the monitoring period. Specifically, continuous water quality data were reviewed immediately following deployment, and if data were rejected, samplers were redeployed immediately.

[2] Look up lists available online at http://swamp.waterboards.ca.gov/swamp_checker/LookUpLists.php
[3] Checker available online at http://swamp.waterboards.ca.gov/swamp_checker/SWAMPUpload.php

For bioassessments, the SMCWPPP field crew made all efforts to collect the required number of BMI and algae subsamples per site; in the event of a dry transect, the samples were slid to the closest sampleable location to ensure 11 total subsamples in each station's composite sample.

2.3.2. Field Sheets

Following the completion of each sampling event, the field crew leader/local monitoring coordinator reviewed any field generated documents for completion, and any missing values were entered. Once field sheets were returned to the office, a second SMCWPPP staff member reviewed the field sheets again and noted any missing data.

2.3.3. Laboratory Results

SMCWPPP staff assessed laboratory reports and EDDs for the number and type of analysis performed to ensure all sites and samples were included in the laboratory results.

2.4. Sensitivity

2.4.1. Biological Data

Benthic macroinvertebrates were identified to SAFIT STE Level I.

2.4.2. Chemical Analysis

The reporting limits for analytical results were compared to the target reporting limits in Appendix E (RMC Target Method Reporting Limits) of the RMC QAPP. Results with reporting limits that exceeded the target reporting limit were flagged.

2.5. Accuracy

2.5.1. Biological Data

Ten percent of the total number of BMI samples collected was submitted to a separate taxonomic laboratory, Jon Lee Consulting, for independent assessment of taxonomic accuracy, enumeration of organisms, and conformance to standard taxonomic level. For SMCWPPP, one sample was evaluated for QC purposes. Results were compared to MQOs in Appendix B (Benthic macroinvertebrate MQOs and Data Production Process).

2.5.2. Chemical Analysis

Caltest and Physis evaluated and reported the percent recovery (PR) of laboratory control samples (LCS; in lieu of reference materials) and matrix spikes (MS), which were recalculated and compared to the applicable MQOs set by Appendix A (Measurement Quality Objectives for RMC Analytes) of the RMC QAPP MQOs. If a QA sample did not meet MQOs, all samples in that batch for that particular analyte were flagged.

For reference materials, percent recovery was calculated as:

$$PR = MV / EV \times 100\%$$

Where: MV = the measured value
EV = the expected (reference) value

For matrix spikes, percent recovery was calculated as:

$$PR = [(MV - NV) / SV] \times 100\%$$

Where: MV = the measured value of the spiked sample
NV = the native, unspiked result
SV = the spike concentration added

2.5.3. Water Quality Data Collection

Accuracy for continuous water quality monitoring sondes was assured via continuing calibration verification for each instrument before and after each two-week deployment. Instrument drift was calculated by comparing the instrument's measurements in standard solutions taken before and after deployment. The drift was compared to measurement quality objectives for drift listed on the SWAMP calibration form, included as an attachment to the RMC SOP FS-3.

Temperature data were checked for accuracy by comparing measurements taken by HOBO temperature loggers with NIST thermometer readings in room temperature water and ice water prior to deployment. The mean difference and standard deviation for each HOBO was calculated, and if a logger had a mean difference exceeding 0.2 °C, it is replaced.

2.6. PRECISION

2.6.1. Field Duplicates

For creek status monitoring, duplicate biological samples were collected at 10% (one) of the 10 probabilistic sites and duplicate water chemistry samples were collected at 10% (one) of the probabilistic sites sampled to evaluate precision of field sampling methods. The RPD for water chemistry field duplicates was calculated and compared to the MQO (RPD < 25%) set by Table 26-1 in Appendix A of the RMC QAPP. If the RPD of the two field duplicates did not meet the MQO, the results were flagged.

The RMC QAPP requires collection and analysis of duplicate sediment chemistry and toxicity samples at a rate of 5% of total samples collected for the project. One field duplicate was collected in San Mateo County for dry weather sediment chemistry, sediment toxicity, and water toxicity samples and an additional field duplicate was collected in Contra Costa County for wet weather pesticides to account for the 16 pesticide & toxicity sites collectively monitored by the RMC in WY 2018. The sediment sample and field duplicate were collected together using the Sediment Scoop Method described in the RMC SOP, homogenized, and then distributed to two separate containers. For sediment chemistry and water pesticides field duplicates, the RPD was calculated for each analyte and compared to the MQOs (RPD < 25%) set by Tables 26-7 through 26-11 in Appendix A of the RMC QAPP. For sediment and water toxicity field duplicates, the RPD of the batch mean was calculated and compared to the recommended acceptable RPD (< 20%) set by Tables 26-12 and 26-13 in Appendix A. If the RPD of the field duplicates did not meet the MQO, the results were flagged.

The RPD is calculated as:

$$RPD = ABS([X1-X2] / [(X1+X2) / 2])$$

Where: X1 = the first sample result
X2 = the duplicate sample result

No field duplicate is required for pathogen indicators.

2.6.2. Chemical Analysis

Caltest and Physis evaluated and reported the RPD for laboratory duplicates, laboratory control duplicates, and matrix spike duplicates. The RPDs for all duplicate samples were recalculated and compared to the applicable MQO set by Appendix A of the RMC QAPP. If a laboratory duplicate sample did not meet MQOs, all samples in that batch for that particular analyte were flagged.

2.7. CONTAMINATION

Blank samples were analyzed for contamination, and results were compared to MQOs set by Appendix A of the RMC QAPP. For creek status monitoring, the RMC QAPP requires all blanks (laboratory and field) to be less than the analyte reporting limits. If a blank sample did not meet this MQO, all samples in that batch for that particular analyte were flagged.

3. RESULTS

3.1. Overall Project Representativeness

The SMCWPPP staff and field crew members were trained in SWAMP and RMC protocols, and received significant supervision from the local monitoring coordinator and QA officer. As a result, creek status monitoring data were considered to be representative of conditions in San Mateo County Creeks.

3.2. Overall Project Comparability

SMCWPPP creek status monitoring data were considered to be comparable to both other agencies in the RMC and to SWAMP due to trainings, use of the same electronic data templates, and close communication.

3.3. Bioassessments and Physical Habitat Assessments

In addition to algae and BMI taxonomic samples, the SMCWPPP field crew collected chlorophyll a and ash free dry mass samples during bioassessments. The BMI taxonomic laboratory, BioAssessment Services, confirmed that the laboratory QA/QC procedures aligned with the procedures in Appendices B through D of the RMC QAPP and met the BMI MQOs in Appendix B.

3.3.1. Completeness

SMCWPPP completed bioassessments and physical habitat assessments for 10 of 10 planned/required sites for a 100% sampling completion rate. However, physical habitat assessments could not be taken at several transects due to inaccessibility.

3.3.2. Sensitivity

The BMI taxonomic identification met sensitivity objectives; the taxonomy laboratory, BioAssessment Services, and QC laboratory, Jon Lee Consulting, confirmed that organisms were identified to SAFIT STE Level I, with the exception of Chironomidae which was analyzed to SAFIT level 1a.

The analytical RL for ash free dry mass analysis (8 mg/L) was much higher than the RMC QAPP target RL of 2 mg/L due to high concentrations requiring large dilutions. The results were several orders of magnitude higher than the actual and target reporting limit and were not affected by the higher RL. While the chlorophyll a analyses also required large dilutions due to high concentrations within the samples, the chlorophyll a analytical RL was below that of the RMC QAPP target RL.

Note that the target RLs in the RMC QAPP are set by the SWAMP, but there are currently no appropriate SWAMP targets for either ash free dry mass or chlorophyll a. Limits in the RMC QAPP are meant to reflect current laboratory capabilities. At lower analyte concentrations where a dilution would not be necessary, the analytical RLs would have met the target RLs.

3.3.3. Accuracy

The BMI sample that was submitted to an independent QC taxonomic laboratory had no taxonomic or counting errors. The QC laboratory calculated sorting and taxonomic identification metrics, which were compared to the measurement quality objectives in Table 27-1 in Appendix B of the RMC QAPP. All MQOs were met. A comparison of the metrics with the MQOs is shown in Table 1. A copy of the QC laboratory report is available upon request.

There is currently no protocol for evaluating the accuracy of algae taxonomic identification.

Table 1. Quality control metrics for taxonomic identification of benthic macroinvertebrates collected in San Mateo County in WY 2018 compared to measurement quality objectives.

Quality Control Metric	MQO	Error Rate	Exceeds MQO?
Recount Accuracy	> 95%	100%	No
Taxa ID	≤ 10%	0%	No
Individual ID	≤ 10%	0%	No
Low Taxonomic Resolution Individual	≤ 10%	0%	No
Low Taxonomic Resolution Count	≤ 10%	0%	No
High Taxonomic Resolution Individual	≤ 10%	0%	No
High Taxonomic Resolution Count	≤ 10%	0%	No

3.3.4. Precision

Field blind duplicate chlorophyll a and ash free dry mass samples were collected at one site in WY 2018 and were sent to the laboratory for analysis.

Duplicate field samples do not provide a valid estimate of precision in the sampling and are of little use to assessing precision, because there is no reasonable expectation that duplicates will produce identical data. Nonetheless, the RPD of the chlorophyll a and ash free dry mass duplicate results were calculated and compared to the MQO (< 25%) for conventional analytes in water (Table 26-1 in Appendix B of the RMC QAPP). Due to the nature of chlorophyll a and ash free dry mass collection, the RPDs for both parameters are expected to exceed the MQO. However, it was found that neither of the RPDs exceeded the MQO this year. The field duplicate results and their RPDs are shown in Table 2.

Again, discrepancies were to be expected due to the potential natural variability in algae production within the reach and the collection of field duplicates at different locations along each transect (as specified in the protocol). As a result, both parameters have frequently exceeded the field duplicate RPD MQOs during past years' monitoring efforts.

Table 2. Field duplicate water chemistry results for sites 202R00614, collected on May 14, 2018

Analyte	Units	202R00614 May 14, 2018			
		Original Result	Duplicate Result	RPD	Exceeds MQO (>25%)[a]
Chlorophyll a	mg/m^2	30.0	32.4	8%	No
Ash Free Dry Mass	g/m^2	48.4	53.9	11%	No

[a]In accordance with the RMC QAPP, if the native concentration of either sample is less than the reporting limit, the RPD is not applicable

Laboratory duplicates were also collected for chlorophyll a and ash free dry mass samples. The RPDs for both chlorophyll a and ash free dry mass were below the MQO limit, and therefore no flagging of samples was required.

3.3.5. Contamination

All field collection equipment was decontaminated between sites in accordance with the RMC SOP FS-8 and CDFW Aquatic Invasive Species Decontamination protocols. As a result, it is assumed that samples were free of biological contamination.

3.4. FIELD MEASUREMENTS

Field measurements of temperature, dissolved oxygen, pH, specific conductivity, and chlorine residual were collected concurrently with bioassessments and water chemistry samples. Chlorine residual was measured using a HACH Pocket Colorimeter™ II, which uses the DPD method. All other parameters were measured with a YSI Professional Plus or YSI 600XLM-V2-S multi-parameter instrument. All data collection was performed according to RMC SOP FS-3 (Performing Manual Field Measurements).

3.4.1. Completeness

Temperature, dissolved oxygen, pH, and specific conductivity were collected at all 10 bioassessment sites for a 100% completeness rate. Free chlorine residual was collected at 9 bioassessment sites for a 90% completeness rate, and total chlorine residual was collected at 8 bioassessment sites for an 80% completeness rate. The lack of chlorine sample collection at two bioassessment sites was due to battery failure in the HACH Pocket Colorimeter used as the sampling device. These circumstances will be avoided in the future by the addition of a back-up battery supply to field supplies.

3.4.2. Sensitivity

Free and total chlorine residual were measured using a HACH Pocket Colorimeter™ II, which uses the DPD method. For this method, the estimated detection limit for the low range measurements (0.02-2.00 mg/L) was 0.02 mg/L. There is, however, no established method reporting limit. Based on industry standards and best professional judgment, the method reporting limit is assumed to be 0.13 mg/L, which is much lower than the 0.5 mg/L target reporting limit listed in the RMC QAPP for free and total chlorine residual.

There are also no method reporting limits for temperature, dissolved oxygen, pH, and conductivity measurements, but the actual measurements are much higher than target reporting limits in the RMC QAPP, so it is assumed that target reporting limits are met for all field measurements.

3.4.3. Accuracy

Data collection occurred Monday through Thursday, and the multi-parameter instrument was calibrated at most 12 hours prior to the first sample on Monday, with the dissolved oxygen sensor calibrated every morning to ensure accurate measurements. Calibration solutions are certified standards, whose expiration dates were noted prior to use. The chlorine kit is factory-calibrated and is sent into the manufacturer every other year to be calibrated.

Free chlorine was measured to be higher than total chlorine at one of the nine sites sampled in WY 2018. In past years, free chlorine has also occasionally been measured as higher than total chlorine. Theoretically, the free chlorine measurement should always be less than or equal to the total chlorine measurement, as the total chlorine concentration in water encompasses the free chlorine concentration in addition to any other chlorine species. The reason for free chlorine concentrations exceeding total chlorine concentrations at a sample site has not been definitively established. However, it is suspected that this could be due to inaccuracy of the chlorine meter at concentrations below 0.13 mg/L or varying chlorine concentrations between the water sample used for the total chlorine measurement and the water sample used for the free chlorine measurement. When free chlorine was observed to be higher than total chlorine at a sample site, the free chlorine measurement was retaken with a new water sample and recorded on the field form. It was deemed unnecessary to flag free chlorine measurements that were higher than total chlorine measurements.

3.4.4. Precision

Precision could not be measured as no duplicate field measurements are required or were collected.

3.5. Water Chemistry

Water chemistry samples were collected by SMCWPPP staff concurrently with bioassessment samples and analyzed by Caltest Analytical Laboratory (Caltest) within their respective holding times. Caltest performed all internal QA/QC requirements as specified in the QAPP and reported their findings to the RMC. Key water chemistry MQOs are listed in RMC QAPP Table 26-2.

3.5.1. Completeness

SMCWPPP collected 100% of planned/required water chemistry samples at the 10 bioassessment sites including one field duplicate sample. Samples were analyzed for all requested analytes, and 100% of results were reported. Water chemistry data were flagged when necessary, but none were rejected.

3.5.2. Sensitivity

Laboratory reporting limits met or were lower than target reporting limits for all nutrients except chloride and nitrate. The reporting limit for all chloride samples exceeded the target reporting limit, but concentrations were much higher than reporting limits, and the elevated reporting limits do not decrease confidence in the measurements.

The reporting limit (0.05 mg/L) and method detection limit (0.02 mg/L) for nitrate samples were higher than the target reporting limit (0.01 mg/L). As a result, the nitrate concentration at one site was measured to be below the method detection limit. SMCWPPP has discussed the reporting limits with Caltest, and there is the possibility for a lower reporting limit for future analysis. Target and actual reporting limits are shown in Table 3.

Table 3. Target and actual reporting limits for nutrients analyzed in SMCWPPP creek status monitoring. Data in highlighted rows exceed monitoring quality objectives in RMC QAPP.

Analyte	Target RL mg/L	Actual RL mg/L
Ammonia	0.02	0.02
Chloride	0.25	1-10
Total Kjeldahl Nitrogen	0.5	0.1
Nitrate	0.01	0.05
Nitrite	0.01	0.005
Orthophosphate	0.01	0.01
Silica	1	1
Phosphorus	0.01	0.01

3.5.3. Accuracy

Recoveries on all LCS were within the MQO target range of 80-120% recovery, and most MS and MSD PRs were within the target range. Three MS/MSD PRs exceeded the MQO range listed in the RMC QAPP for conventional analytes, including ammonia and silica. The QA samples affected five sites, whose results have been assigned the appropriate SWAMP flag. Though the data were flagged, none of the analytical data were rejected by the local QA officer due to accuracy.

The PR ranges on laboratory reports were 70-130%, 85-115% or 90-110% for some conventional analytes (nutrients) while the RMC QAPP lists the PR as 80-120% for all conventional analytes in water. As a result, some QA samples that exceeded RMC MQOs were flagged by the local QA officer, but not by the laboratory and vice versa.

3.5.4. Precision

The RPD for all laboratory control sample and MS/MSD pairs were consistently below the MQO target of < 25%.

Water chemistry field duplicates were collected at one site in San Mateo County and were compared against the original samples. For WY 2018, the total Kjeldahl nitrogen and ammonia duplicate samples exceeded the RPD MQO. In past years of sampling, total Kjeldahl nitrogen has been common among the analytes that exceed the field duplicate RPD MQOs. Field crews will continue to make an effort in subsequent years to collect the original and duplicate samples in an identical fashion.

The field duplicate water chemistry results and their RPDs are shown in Table 4. Because of the variability in reporting limits, values less than the RL were not evaluated for RPD. For those analytes whose RPDs could be calculated and did not meet the RMC MQO, they were assigned the appropriate SWAMP flag.

Table 4. Field duplicate water chemistry results for site 202R00614, collected on May 14, 2018. Data in highlighted rows exceed measurement quality objectives in RMC QAPP.

Analyte Name	Fraction Name	Unit	Original Result	Duplicate Result	RPD	Exceeds MQO (>25%)[a]
Ammonia as N	Total	mg/L	0.048	0.033	37%	Yes
Chloride	None	mg/L	38	38	0%	No
Nitrate as N	None	mg/L	0.06	ND	N/A	N/A
Nitrite as N	None	mg/L	J 0.001	J 0.001	N/A	N/A
Nitrogen, Total Kjeldahl	None	mg/L	0.44	0.31	35%	Yes
Orthophosphate as P	Dissolved	mg/L	0.1	0.1	0%	No
Phosphorus as P	Total	mg/L	0.12	0.11	9%	No
Silica as SiO2	Total	mg/L	23	22	4%	No

[a]In accordance with the RMC QAPP, if the native concentration of either sample is less than the reporting limit, the RPD is not applicable

3.5.5. Contamination

None of the target analytes were detected in any of the laboratory blanks at levels above their reporting limit. All analytes were non-detect in the laboratory blanks. The RMC QAPP does not require field blanks to be collected, and possible contamination from sample collection was not assessed. However, the SMCWPPP field crew takes appropriate precautions to avoid contamination, including wearing gloves during sample collection and rinsing sample containers with stream water when preservatives are not needed.

3.6. Pathogen Indicators

Pathogen indicator samples were collected by SMCWPPP staff and were analyzed by Alpha Analytical Laboratories, Inc for *E. coli* and enterococcus. Samples were collected on July 27, 2018.

3.6.1. Completeness

All five required/planned pathogen indicator samples were collected for a 100% completeness rate. However, the samples taken at site 202PES150 and 202PES154 were not analyzed within the eight-hour hold time specified by the RMC QAPPP. The sample from site 202PES150 was analyzed 55 minutes after the eight-hour hold time limit, and the sample from site 202PES154 was analyzed 50 minutes after the limit. These hold time limit exceedances are not expected to have affected the integrity of the sample results. As a result, these were flagged but not rejected.

3.6.2. Sensitivity

The reporting limits for *E. coli* and enterococcus (1 MPN/100mL and 2 MPN/100mL, respectively) met the target RL of 2 MPN/100mL listed in the project QAPP.

3.6.3. Accuracy

Negative and positive laboratory controls were run for microbial media. A negative response was observed in the negative control and a positive response was observed in the positive control required by the project QAPP Table 26-4.

3.6.4. Precision

The RMC QAPP requires one laboratory duplicate to be run per 10 samples or per analytical batch, whichever is more frequent. However, determining precision for pathogen indicators requires 15 duplicate sets. Due to the small number of samples collected for this project, there were not enough laboratory duplicates to determine precision. In WY 2018, only one laboratory duplicate was run and is not sufficient in determining precision.

The RMC QAPP does not require a field duplicate to be collected for pathogen indicators. However, one field duplicate was collected in WY 2018 by the field crew for a different project. The RPD for *E. coli* was 75% and 17% for enterococcus. Since there is no requirement for pathogen field duplicates, there is no corresponding MQO, and the precision could not be assessed. See Table 5 for the field duplicate results.

Table 5. Lab and field duplicate pathogen results collected on July 27, 2018.

Duplicate Type	Analyte	Original Result (MPN/100mL)	Duplicate Result (MPN/100mL)	RPD
Lab Duplicate	E. coli	> 2419.6	> 2419.6	NA
Lab Duplicate	Enterococcus	> 2419.6	> 2419.6	NA
Field Duplicate	E. coli	260.3	275.5	6%
Field Duplicate	Enterococcus	547.5	410.6	29%

3.6.5. Contamination

One method blank (sterility check) was run in the batch for *E. coli* and enterococcus. No growth was observed in the blank.

3.7. Continuous Water Quality

Continuous water quality measurements were recorded at two sites during the spring (May 2018), concurrent with bioassessments, and again in the summer (August 2018) in compliance with the MRP. Temperature, pH, dissolved oxygen, and specific conductivity were recorded once every 15 minutes for approximately two-weeks using a multi-parameter water quality sonde (YSI 6600-V2).

3.7.1. Completeness

The MRP requires one to two-week deployments, and both deployments exceeded the one week minimum. The first deployment lasted 13 days, while the second deployment lasted 11 days at site 202SPE040 and 9 days at 202SPE070. Due to an internal malfunction in the sonde deployed at site 202SPE070 during the second deployment, the sonde did not record the first two days of its deployment.

As a result, that sonde collected 81% of the planned deployment. The other sondes collected data for 100% of the planned deployments, and no data were rejected.

3.7.2. Sensitivity

There are no method reporting limits for temperature, dissolved oxygen, pH, and conductivity measurements, but the actual measurements are much higher than target reporting limits in the RMC QAPP, so it is assumed that target reporting limits are met for all field measurements.

3.7.3. Accuracy

The SMCWPPP staff conduct pre- and post-deployment sonde calibrations for the two sondes used during monitoring events and calculate the drift during the deployments. A summary of the drift measurements is shown in Table 6. During the second monitoring event, the sonde deployed at 202SPE040 exceeded the drift MQO for dissolved oxygen. Oxygen results at this site were subsequently flagged for this deployment, but not rejected.

Table 6. Drift measurements for two continuous water quality monitoring events in San Mateo County urban creeks during WY 2018. Bold and highlighted values exceeded measurement quality objectives.

Parameter	Measurement Quality Objectives	202SPE040		202SPE070	
		Event 1	Event 2	Event 1	Event 2
Dissolved Oxygen (mg/l)	± 0.5 mg/L or 10%	0.16	0.11	-0.19	0.07
pH 7.0	± 0.2	0.11	0.01	0.02	0.12
pH 10.0	± 0.2	0.12	-0.04	-0.01	0.07
Specific Conductance (uS/cm)	± 10%	0.8%	-0.6%	0.8%	-9.1%

3.7.4. Precision

There is no protocol listed in the RMC QAPP for measuring the precision of continuous water quality measurements.

3.8. Continuous Temperature Monitoring

Continuous temperature monitoring was conducted from April through September 2018 at five sites in San Mateo County. Onset HOBO Water Temperature data loggers recorded one measurement per hour.

3.8.1. Completeness

The MRP requires SMCWPPP to monitor four stream reaches for temperature each year, but anticipating the potential for a HOBO temperature logger to be lost during such a long deployment, SMCWPPP deployed one extra temperature logger for a total of five loggers. In the middle of the deployment, SMCWPPP staff checked the loggers to ensure that they were still present and recording. One logger was missing during the mid-deployment field check and was replaced with another logger. During the field check, staff also downloaded the existing data and redeployed the other loggers. Since the other four loggers recorded 100% of the deployment period, SMCWPPP was still able to achieve a completion rate of over 100%.

3.8.2. Sensitivity

There is no target reporting limit for temperature listed in the RMC QAPP, thus sensitivity could not be evaluated for continuous temperature measurements.

3.8.3. Accuracy

A pre-deployment accuracy check was run on the temperature loggers in March 2018. None of the loggers exceeded the 0.2 °C mean difference threshold for either the room temperature bath or the 0.2 °C mean difference for the ice bath. The loggers were subsequently deployed, and no flagging of the data was necessary.

3.8.4. Precision

There are no precision protocols for continuous temperature monitoring.

3.9. SEDIMENT CHEMISTRY

The dry season sediment chemistry sample was collected by Kinnetic Laboratories, Inc (KLI) concurrently with the dry season toxicity sample on July 17, 2018. Inorganic and synthetic organic compounds were analyzed by Caltest and grain size distribution was analyzed by Soil Control Laboratories, a subcontractor laboratory. Caltest conducted all QA/QC requirements as specified in the RMC QAPP and reported their findings to the RMC. Key sediment chemistry MQOs are listed in RMC QAPP Tables 26-9 through 26-11. Sediment chemistry data were flagged when necessary, but none were rejected

3.9.1. Completeness

The MRP requires a sediment chemistry sample to be collected at one location each year. In WY 2018, SMCWPPP collected the sediment chemistry sample at 204COR010. The laboratories analyzed samples within the one year holding time for analytes in sediment, set by the RMC SOP, and reported 100% of the required analytes.

3.9.2. Sensitivity

A comparison of target and actual reporting limits for those parameters is shown in Table 7. For sediment chemistry analysis conducted in WY 2018, laboratory reporting limits were higher than RMC QAPP target reporting limits for all 20 analytes. Since reporting limits for a sample are dependent on the percent solids of that sample, it is likely that the amount of solids in the sample resulted in these exceedances.

Table 7. Comparison of target and actual reporting limits for sediment analytes where reporting limits exceeded target limits. Sediment samples were collected in San Mateo County creeks in WY 2018.

Analyte	Target RL	Actual RL	Unit
Arsenic	0.3	1.0	mg/Kg
Cadmium	0.01	0.08	mg/Kg
Chromium	0.1	1	mg/Kg
Copper	0.01	0.41	mg/Kg
Lead	0.01	0.08	mg/Kg
Nickel	0.02	0.08	mg/Kg
Zinc	0.1	0.8	mg/Kg
Bifenthrin	0.33	1.3	ng/g
Cyfluthrin	0.33	1.3	ng/g
Total Lambda-cyhalothrin	0.33	1.3	ng/g
Total Cypermethrin	0.33	1.3	ng/g
Total Deltamethrin	0.33	1.3	ng/g
Total Esfenvalerate/Fenvalerate	0.33	1.3	ng/g
Permethrin	0.33	1.3	ng/g
Carbaryl	30	31	ng/g
Fipronil	0.33	1.3	ng/g
Fipronil Desulfinyl	0.33	1.3	ng/g
Fipronil Sulfide	0.33	1.3	ng/g
Fipronil Sulfone	0.33	1.3	ng/g
Total Organic Carbon	0.01	0.05	% dw

3.9.3. Accuracy

Inorganic Analytes

No QA samples exceeded the QAPP MQO for LCS percent recovery (PR) for metals (75-125%), but theMSD sample for lead exceeded the PR MQO. This sample was flagged but not rejected.

Synthetic Organic Compounds

The percent recovery MQO for pyrethroids and other synthetic organic compounds in sediment is 50-150% in the RMC QAPP. However, the PR MQOs listed in the laboratory reports for synthetic organic compounds varied by analyte and were much larger than PR ranges listed in the QAPP. The MQOs ranged from 1 to 275% in certain cases. As a result, several analytes were flagged by the local QA officers, but not by the laboratory.

None of the LCS PRs exceeded the RMC MQO range. However, the MS/MSD PRs exceeded the RMC MQO range for 10 PAHs, one pyrethroid (bifenthrin), and fipronil. The PAH MS/MSD samples that exceeded the PR MQO include benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(e)pyrene, benzo(g,h,i)perylene, benzo(k)fluoranthene, dibenzo(a,h)anthracene, indeno(1,2,3-cd)pyrene, perylene, and pyrene.

3.9.4. Precision

Inorganic Analytes

The RMC QAPP lists the maximum RPD for inorganic analytes (metals) as 25%. All MS/MSD sets for metals were well below the RMC RPD MQO of 25%.

Synthetic Organic Compounds

The maximum RPD for synthetic organics listed in the sediment laboratory report lists ranges from 30 to 50% for most analytes. However, the RMC QAPP lists the MQO as < 25% RPD for most synthetic organics, < 35% for pyrethroids and fipronil, and < 40% for carbaryl. None of the MS/MSD pairs or LCS duplicates exceeded the RPD MQO.

Field Duplicates

A sediment sample field duplicate was collected in San Mateo County on July 17, 2018 and evaluated for precision. The field duplicate sample and corresponding RPDs are shown in Table 8. Because of the variability in reporting limits, values less than the RL were not evaluated for RPD. The measured concentrations of a majority of analytes from the original and duplicate samples were below the method detection limit and therefore reported as "ND". As a result, the RPDs were non-calculable. All calculable RPDs were below the MQO limits. Analytes that exceeded the MQO of RPD < 25% were cadmium; chromium; lead; anthracene; benz(a)anthracene; chrysene; dimethylnaphthalene, 2,6-; fluoranthene; methylnaphthalene, 1-; methylnaphthalene, 2-; naphthalene; phenanthrene; and pyrene.

Table 8. Sediment chemistry duplicate field results for site 204COR010, collected on July 17, 2018 in San Mateo County. Data in highlighted rows exceed monitoring quality objectives in RMC QAPP.

Analyte		Unit	Original	Duplicate	RPD	Exceeds MQO? (<25%)[a]
Grain Size Distribution	Clay: <0.0039 mm	%	3.35	3.36	0%	No
	Silt: 0.0039 to <0.0625 mm	%	7.38	7.22	2%	No
	Sand: V. Fine 0.0625 to <0.125 mm	%	4.72	4.78	1%	No
	Sand: Fine 0.125 to <0.25 mm	%	13.39	13.79	3%	No
	Sand: Medium 0.25 to <0.5 mm	%	26.74	27.12	1%	No
	Sand: Coarse 0.5 to <1.0 mm	%	27.42	27.14	1%	No
	Sand: V. Coarse 1.0 to <2.0 mm	%	17.01	16.59	2.5%	No
	Granule: 2.0 to <4.0 mm	%	10.56	9.24	13%	No
	Pebble: Small 4 to <8 mm	%	13.14	12.64	4%	No
	Pebble: Medium 8 to <16 mm	%	ND	6.09	N/A	N/A
	Pebble: Large 16 to <32 mm	%	ND	ND	N/A	N/A
	Pebble: V. Large 32 to <64 mm	%	ND	ND	N/A	N/A
Metals	Arsenic	mg/Kg dw	4.1	4.1	0%	No
	Cadmium	mg/Kg dw	0.12	0.09	29%	Yes
	Chromium	mg/Kg dw	91	55	49%	Yes
	Copper	mg/Kg dw	25	23	8%	No
	Lead	mg/Kg dw	15	38	87%	Yes
	Nickel	mg/Kg dw	92	74	22%	No
	Zinc	mg/Kg dw	78	75	4%	No
Pyrethroids (MQO <35%)	Bifenthrin	ng/g dw	1.2	1.1	9%	No
	Cyfluthrin, total	ng/g dw	ND	0.6	N/A	N/A
	Cyhalothrin, Total lambda-	ng/g dw	ND	ND	N/A	N/A
	Cypermethrin, total	ng/g dw	ND	ND	N/A	N/A
	Deltamethrin/Tralomethrin	ng/g dw	0.69	ND	N/A	N/A
	Esfenvalerate/Fenvalerate, total	ng/g dw	ND	ND	N/A	N/A
	Permethrin, Total	ng/g dw	0.81	0.81	0%	No
	Total Organic Carbon	%	0.92	0.93	1%	No
	Carbaryl	mg/Kg dw	ND	ND	N/A	N/A
Fipronil	Fipronil	ng/g dw	ND	ND	N/A	N/A
	Fipronil Desulfinyl	ng/g dw	ND	ND	N/A	N/A

Table 8. Sediment chemistry duplicate field results for site 204COR010, collected on July 17, 2018 in San Mateo County. Data in highlighted rows exceed monitoring quality objectives in RMC QAPP.

	Analyte	Unit	Original	Duplicate	RPD	Exceeds MQO? (<25%)[a]
	Fipronil Sulfide	ng/g dw	ND	ND	N/A	N/A
	Fipronil Sulfone	ng/g dw	ND	ND	N/A	N/A
Polycyclic Aromatic Hydrocarbons	Acenaphthene	ng/g dw	ND	ND	N/A	N/A
	Acenaphthylene	ng/g dw	ND	ND	N/A	N/A
	Anthracene	ng/g dw	3.1	4.1	28%	Yes
	Benz(a)anthracene	ng/g dw	4.1	6.1	39%	Yes
	Benzo(a)pyrene	ng/g dw	ND	ND	N/A	N/A
	Benzo(b)fluoranthene	ng/g dw	ND	ND	N/A	N/A
	Benzo(e)pyrene	ng/g dw	ND	ND	N/A	N/A
	Benzo(g,h,i)perylene	ng/g dw	ND	ND	N/A	N/A
	Benzo(k)fluoranthene	ng/g dw	ND	ND	N/A	N/A
	Biphenyl	ng/g dw	8.2	10	20%	No
	Chrysene	ng/g dw	21	31	38%	Yes
	Dibenz(a,h)anthracene	ng/g dw	ND	ND	N/A	N/A
	Dibenzothiophene	ng/g dw	ND	ND	N/A	N/A
	Dimethylnaphthalene, 2,6-	ng/g dw	7.2	20	94%	Yes
	Fluoranthene	ng/g dw	21	31	38%	Yes
	Fluorene	ng/g dw	ND	ND	N/A	N/A
	Indeno(1,2,3-c,d)pyrene	ng/g dw	ND	ND	N/A	N/A
	Methylnaphthalene, 1-	ng/g dw	7.2	10	33%	Yes
	Methylnaphthalene, 2-	ng/g dw	10	20	67%	Yes
	Methylphenanthrene, 1-	ng/g dw	ND	ND	N/A	N/A
	Naphthalene	ng/g dw	6.2	10	47%	Yes
	Perylene	ng/g dw	ND	ND	N/A	N/A
	Phenanthrene	ng/g dw	21	51	83%	Yes
	Pyrene	ng/g dw	21	31	38%	Yes

[a] MQO for pyrethroids is <35%. In accordance with the RMC QAPP, if the native concentration of either sample is less than the reporting limit, the RPD is not applicable

<u>Laboratory Duplicates</u>

Laboratory duplicates were collected and analyzed for grain sizes and total organic carbon. All RPDs were below the MQO limits except for small (4 to <8 mm) and medium (8 to <16 mm) pebbles in addition to coarse (0.5 to <1.0 mm) and very coarse (1.0 to <2.0 mm) sand.

3.9.5. Contamination

Nickel was detected in an instrument (lab) blank at a concentration above the reporting limit. As a result, nickel samples were flagged. None of the other target analytes were detected in any of the blanks.

3.10. Wet Season Pesticides

Wet season pesticide samples were collected by KLI concurrently with the wet season toxicity sample on January 8, 2018. Samples were analyzed by Physis Environmental Laboratories, Inc. within their respective hold times for pesticides, including pyrethroids, fipronil, fipronil degredates, and imidacloprid. Physis conducted all QA/QC requirements as specified in the RMC QAPP and reported their findings to the RMC. Key water chemistry MQOs are listed in RMC QAPP Tables 26-9 through 26-11. Water chemistry data were flagged when necessary, but none were rejected.

3.10.1. Completeness

The MRP requires the RMC to collect ten water column pesticides samples over the permit term if sampling is conducted by the RMC on behalf of all Permittees. Permittees have decided to collaborate, and in WY 2018, two samples were collected in San Mateo County at 202SPE005 and 204COR010. A total of ten samples were collected by the RMC on behalf of Permittees in WY 2018. The laboratories analyzed and reported 100% of the planned/required analytes.

3.10.2. Sensitivity

The reporting limits for analytes collected in WY 2018 were all below the target reporting limits specified in the RMC QAPP.

3.10.3. Accuracy

The percent recovery MQO for pyrethroids and other synthetic organic compounds in sediment is 50-150% in the RMC QAPP. None of the LCS percent recoveries exceeded the RMC MQO range. However, the MS/MSD percent recoveries exceeded the RMC MQO range for three compounds including fipronil, fipronil desulfinyl, and fipronil sulfide.

3.10.4. Precision

The RPD listed in the laboratory report for water column pesticides is listed as 30%. However, the RMC QAPP lists the MQO as < 25% RPD for most synthetic organics and < 35% for pyrethroids and fipronil. None of the MS/MSD pairs or LCS duplicates exceeded the RPD MQOs.

Field Duplicates

A field duplicate was collected in Contra Costa County on January 8, 2018 and evaluated for precision. The field duplicate sample and corresponding RPDs are shown in Table 9. Because of the variability in reporting limits, values less than the Reporting Limit (RL) were not evaluated for RPD. The measured concentrations of a majority of analytes from the original and duplicate samples were below the method detection limit and therefore reported as ND, meaning that the RPDs were non-calculable. All calculable RPDs were below the MQO limits.

Table 9. Water column pesticides duplicate field results for site 204R01412, collected on January 8, 2018 in San Mateo County. Data in highlighted rows exceed monitoring quality objectives in RMC QAPP.

Analyte		Unit	Original	Duplicate	RPD	Exceeds MQO? (<25%)[a]
Pyrethroids (MQO <35%)	Bifenthrin	ug/L	0.017	0.019	8%	No
	Cyfluthrin, total	ug/L	ND	ND	N/A	N/A
	Cyhalothrin, Total Lambda-	ug/L	ND	ND	N/A	N/A
	Cypermethrin, total	ug/L	ND	ND	N/A	N/A
	Deltamethrin/Tralomethrin	ug/L	ND	ND	N/A	N/A
	Esfenvalerate	ug/L	ND	ND	N/A	N/A
	Fenvalerate	ug/L	ND	ND	N/A	N/A
	Permethrin, cis-	ug/L	ND	ND	N/A	N/A
	Permethrin, trans-	ug/L	ND	ND	N/A	N/A
	Imidacloprid	ug/L	0.050	0.059	16%	No
Fipronil	Fipronil	ug/L	0.024	0.022	8%	No
	Fipronil Desulfinyl	ug/L	0.009	0.009	1%	N/A[b]
	Fipronil Sulfide	ug/L	0.002	0.002	9%	N/A[b]
	Fipronil Sulfone	ug/L	0.016	0.015	9%	N/A[b]

[a] MQO for pyrethroids is <35%. In accordance with the RMC QAPP, if the native concentration of either sample is less than the reporting limit, the RPD is not applicable.

[b]No MQO is listed in the RMC QAPP for Fipronil Desulfinyl, Sulfide, or Sulfone.

<u>Laboratory Duplicates</u>

Laboratory duplicates were collected and analyzed for all wet weather pesticides analytes in addition to total organic carbon. All RPDs were below the MQO limits except for imidacloprid. As a result, the imidacloprid samples were flagged.

3.10.5. Contamination

No target analytes were detected in corresponding instrument (lab) blanks at a concentration above their reporting limits. As a result, no samples were flagged.

3.11. Toxicity Testing

Dry season water and sediment toxicity samples were collected by KLI concurrently with dry season sediment chemistry samples at one San Mateo County site on July 17, 2018. All toxicity tests were performed by Pacific EcoRisk. The water samples were analyzed for toxicity to five organisms (*Selenastrum capricornutum, Ceriodaphnia dubia, Pimephales promelas, Hyalella azteca, and Chironomus dilutus*) and the sediment samples were analyzed for toxicity to *Hyalella azteca* and *Chironomus dilutus.*

Wet season water toxicity samples were collected by KLI concurrently with wet season water column pesticides samples at two San Mateo County sites on January 8, 2018. All wet season water toxicity tests were also performed by Pacific EcoRisk. The samples were analyzed for toxicity to five organisms (*Selenastrum capricornutum, Ceriodaphnia dubia, Pimephales promelas, Hyalella azteca, and Chironomus dilutus*).

3.11.1. Completeness

The MRP requires the collection of dry season water and sediment toxicity samples at one site per year in San Mateo County. Additionally, the MRP requires ten wet season water toxicity samples to be collected by the RMC participants over the permit term. SMCWPPP staff collected a wet season water toxicity sample in WY 2018. Pacific EcoRisk tested the required organisms for toxicity, and 100% of results were reported.

3.11.2. Sensitivity and Accuracy

Internal laboratory procedures that align with the RMC QAPP, including water and sediment quality testing and reference toxicant testing, were performed and submitted to SMCWPPP. The laboratory data QC checks found that all conditions and responses were acceptable. A copy of the laboratory QC report is available upon request.

3.11.3. Precision

One field duplicate was collected in San Mateo County on behalf of the RMC and tested for toxicity by Pacific EcoRisk. The mean toxicity endpoints of test organisms (mean survival, mean cell count, mean biomass, and mean young per female) for the field duplicates were compared, and the RPD for each toxicity test was calculated. These RPDs are compared to the RMC QAPP MQO of <20% for acute and chronic freshwater toxicity testing (Appendix A, Table 26-12 and 26-13) in Table 10. There is no MQO for sediment toxicity field duplicates listed in the RMC QAPP, so the recommended MQO listed in the RMC QAPP for the water toxicity field duplicates (< 20%) was used as an MQO for the sediment toxicity field duplicates. Samples met the MQO for toxicity testing for all species and endpoints.

Table 10. Water and sediment toxicity duplicate results for site 204COR010, collected on July 17, 2018 in San Mateo County. Data in highlighted rows exceed monitoring quality objectives in RMC QAPP.

Matrix	Organism	Endpoint	Original Sample Mean	Duplicate Sample Mean	RPD	Exceeds Recommended MQO (<20%)?
Water	Pimephales promelas	% Survival	95	97.5	3%	No
Water	Pimephales promelas	Biomass (mg/individual)	0.905	0.959	6%	No
Water	Ceriodaphnia dubia	% Survival	100	100	0%	No
Water	Ceriodaphnia dubia	Young per female	33	32	3%	Yes
Water	Selenastrum capricornutum	Total Cell Count (cells/mL)	8680000	8960000	3%	No
Water	Hyalella azteca	% Survival	98	100	2%	No
Water	Chironomus dilutus	% Survival	85	85	0%	No
Sediment	Hyalella azteca	% Survival	95	91.3	4%	No
Sediment	Chironomus dilutus	% Survival	88.8	81.2	9%	No

3.11.4. Contamination

There are no QA/QC procedures for contamination of toxicity samples, but staff followed applicable RMC SOPs to limit possible contamination of samples.

4. CONCLUSIONS

Sample collection and analysis followed MRP and RMC QAPP requirements and data that exceeded measurement quality objectives were flagged. However, no data were rejected.

5. REFERENCES

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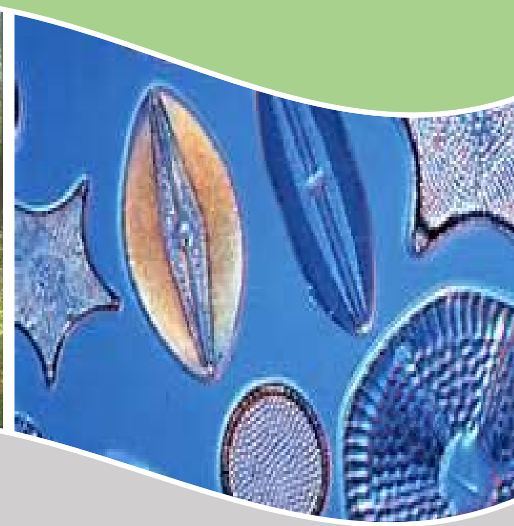
Attachment 2

RMC 5-Year Report

BASMAA Regional Monitoring Coalition Five-Year Bioassessment Report

Water Years 2012 - 2016





Prepared for:

Bay Area Stormwater Management Agencies Association

Prepared by:

EOA inc.

APPLIED MARINE SCIENCES

March 2019

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Executive Summary

Biological assessment (bioassessment) is an evaluation of the biological condition of a water body based on the organisms living within it. In 2009, the Bay Area Stormwater Management Agencies Association's (BASMAA) Regional Monitoring Coalition (RMC) developed a bioassessment monitoring program to answer management questions identified in the Municipal Regional Stormwater National Pollutant Discharge Elimination System (NPDES) Permit (referred to as the Municipal Regional Permit or MRP):

- *Are water quality objectives, both numeric and narrative, being met in local receiving waters, including creeks, rivers and tributaries?*
- *Are conditions in local receiving waters supportive or likely to be supportive of beneficial uses?*

Bioassessment data collected over the first five years of RMC monitoring (2012-2016) are included in this report. The RMC's monitoring design addresses these management questions on a regional (Bay Area) scale to monitoring results across the five participating Bay Area counties (Alameda, Contra Costa, San Mateo, Santa Clara and Solano). Three study questions, developed to assist with addressing the management questions described above, including:

1) What is the biological condition of perennial and non-perennial streams in the region?
2) What stressors are associated with poor condition?
3) Are conditions changing over time?

The findings of this study are intended to help stormwater programs better understand the current condition of these water bodies and identify stressors that are likely to pose the greatest risk to the health of streams in the Bay Area. The report evaluates the existing RMC monitoring design and identifies a range of potential options for revising the design (if desired) to better address the questions posed. These options are intended to provide considerations for discussion during the planning for reissuance of the Municipal Regional Permit, which is likely to be adopted in 2020 or 2021.

Key Findings

- **Most streams in the region are in poor biological condition.** The biological conditions of streams in the RMC area are assessed using two ecological indicators: benthic macroinvertebrates (BMIs) and algae. Results from 2012 through 2016 study period indicate that streams in the RMC area are generally in poor biological condition. Based on BMIs, over half (58%) of stream length was ranked in the lowest condition category of the California Stream Condition Index (CSCI). For algae indices (D18 and S2), stream conditions appear slightly less degraded, with approximately 40% of the streams ranked in lowest condition category. These findings should be interpreted with the understanding that the survey focused on urban stream conditions, and that these data represent current (baseline) conditions.

- **Poor biological conditions are strongly associated with physical habitat and landscape stressors.** The associations between biological indicators (CSCI and D18) and stressor data were evaluated using random forest and relative risk analyses. The study results showed that different biological indicators responded to different types of stressors. CSCI scores were strongly influenced by physical habitat variables (e.g., level of human disturbance at a site) and land use factors (e.g., level of impervious surfaces near the site), while D18 scores were moderately influenced by water quality variables (e.g., dissolved oxygen and conductivity). Together, BMI and algae indices can be used to assess the overall biological condition of water bodies and potentially identify the causes of poor (or good) conditions. In general, CSCI scores at urban sites were consistently low, indicating that degraded physical habitat conditions common in urban settings are impacting biological conditions in streams. In contrast, D18 scores at urban sites were more variable, indicating that healthy diatom (algae) assemblages can occur at sites with poor physical habitat, which may provide valuable information about the overall water quality conditions in urban streams.

- **No changes in biological conditions are evident over the 5-year survey.** The short time frame of the survey (five years) limited the ability to detect trends. The variability in biological condition observed over the five years of the current analysis may have been associated with annual variation in precipitation, which included drought conditions during the first four years of the survey. A longer time period may be needed to detect trends in biological condition at a regional scale.
- **Baseline biological assessment data can assist Bay Area stormwater managers in evaluating the long-term effectiveness of ongoing or planned management actions.** Baseline bioassessment monitoring data collected by the RMC provides valuable information about the current status of aquatic life uses in the Bay Area and how RMC streams compare to other regions in the State of California. The baseline dataset provides context for potential future biological integrity policies being developed by the State Water Resources Control Board (State Water Board) and serves as a foundation for evaluating on-going and future watershed management actions that attempt to reduce the impacts of urbanization on creeks and channels. Future creek status monitoring may provide additional insight into the potential positive impacts of actions, such as green stormwater infrastructure and creek restoration, that improve water quality and address other needs of aquatic life uses in urban creeks.
- **The RMC monitoring design provides estimates for overall stream conditions in RMC area and urban stream conditions for each county.** Because participating municipalities are primarily concerned with stormwater runoff from urban areas, the RMC focused sampling efforts on urban sites (approximately 80%) over non-urban sites (approximately 20%). As a result, non-urban sites are under-represented in the dataset, resulting in lower overall biological condition scores than would be expected for a spatially balanced dataset. Depending on the goals for the RMC moving forward, consideration should be given to developing a new sample draw that establishes a new list of assessment sites that are weighted for specific land uses categories and Program areas of interest. Based on evaluation of data collected during the first five years of the survey, several options to revise the RMC Monitoring Design are presented in the report.

1 INTRODUCTION

1.1 BACKGROUND

The Bay Area Stormwater Management Agencies Association (BASMAA) Regional Monitoring Coalition (RMC) is a consortium of six San Francisco Bay Area municipal stormwater programs that joined together in 2010 to coordinate and oversee water quality monitoring required by the Municipal Regional Stormwater National Pollutant Discharge Elimination System (NPDES) Permit (referred to as the Municipal Regional Permit or "MRP"). The MRP was first adopted in 2009 (Order R2-2009-0074) by the San Francisco Bay Regional Water Quality Control Board (SFBRWQCB). The MRP was reissued in 2015 through Order R2-2015-1049. The 2009 and 2015 versions of the MRP are referred to as MRP 1.0 and MRP 2.0, respectively. Both versions of the MRP require bioassessment monitoring in accordance with Standard Operating Procedures (SOPs) established by the California Surface Water Ambient Monitoring Program (SWAMP), including sampling of benthic macroinvertebrates (BMIs), benthic algae (i.e., diatoms and soft algae), and water chemistry, and the characterization of physical habitat.

The MRP identifies two broad management questions that required bioassessment monitoring (and other creek status monitoring requirements) is intended to address:

- *Are water quality objectives, both numeric and narrative, being met in local receiving waters, including creeks, rivers and tributaries?*
- *Are conditions in local receiving waters supportive or likely to be supportive of beneficial uses?*

Consistent with the requirements of the MRP, the RMC developed a probabilistic monitoring design to address the management questions on a regional scale and compare monitoring results across stormwater programs. The probabilistic design is based on the Generalized Random Tessellation Stratified (GRTS) approach (Stevens and Olson 2004) for evaluating and selecting sampling stations in perennial and nonperennial streams. A power analysis estimated a minimum sample size of 30 sites to evaluate the condition of aquatic life within a confidence interval of approximately 12%. This was considered sufficient for decision-making in the RMC area. Under the MRP, each municipal Stormwater Program is required to assess a minimum number of stream/channel sites based on their relative population. As a result, the number of sites required each year varies by county: 20 sites for Santa Clara and Alameda counties and 10 sites for San Mateo and Contra Costa counties. Fairfield-Suisun and Vallejo are required to sample 8 and 4 sites, respectively, during each five-year period. In addition, the San Francisco Bay Regional Water Quality Control Board (SF Bay Water Board) collaborated with the RMC by monitoring additional sites in non-urban areas in each of the counties.

1.2 PROJECT GOAL

This goal of this project was to compile and evaluate bioassessment data collected over the first 5-years of bioassessment monitoring conducted by the RMC (2012 – 2016). The evaluation was designed to address three main questions, consistent with the overarching questions in the MRP:

1) What is the biological condition of perennial and non-perennial streams in the region?

2) What stressors are associated with poor condition?
3) Are conditions changing over time?

The findings of this report are intended to help stormwater programs better understand the current condition of these water bodies, prioritize stream reaches in need of protection or restoration, and identify stressors that are likely to pose the greatest risk to the health of streams in the Bay Area.

This report also provides an evaluation of the existing RMC monitoring design and identifies a range of potential options for revising the design (if desired) in anticipation of the next version of the MRP, which is likely to be adopted in 2020 or 2021. These options can inform the monitoring re-design process as part of a future BASMAA Regional Project.

This project was implemented by a Project Team comprised of EOA, Inc. and Applied Marine Sciences, Inc. (AMS) with technical review provided by the Southern California Coastal Water Research Project (SCCWRP). A BASMAA Project Management Team (PMT) consisting of representatives from BASMAA stormwater programs and municipalities provided oversight and guidance to the Project Team.

Sections of this report are organized according to the following topics:

- **Section 1.0** – Introduction including summary of other Regional Monitoring Programs using biological assessments, development of State policies that are relevant to bioassessment data collection, and description of the goals for this report;
- **Section 2.0** – Methods including monitoring survey design, site evaluation procedures, field sampling and data analyses;
- **Section 3.0** – Results summarizing biological conditions, stressor association with conditions, and trends;
- **Section 4.0** – Discussion organized by the management questions and goals; and
- **Section 5.0** – Conclusions and recommendations.

1.3 Bioassessments Programs in California

Bioassessment programs are currently implemented on a statewide and regional basis in California. The RMC's monitoring design is consistent with the design used by the statewide Perennial Streams Assessment (PSA) program and is specifically intended to allow for future integration of data between the two monitoring programs. The RMC has also integrated lessons learned from the Stormwater Monitoring Coalition (SMC), which spearheads a similar collaborative monitoring effort in Southern California, in the development of alternatives for potential re-design of the RMC monitoring survey described at the end of this report.

Since 2000, the State of California has conducted probability surveys of its perennial streams and rivers with a focus on biological endpoints. These surveys are managed collectively by the Surface Water Ambient Monitoring Program (SWAMP) under its PSA program. The PSA collects samples for biological indicators (BMIs and algae), chemical constituents (nutrients, major ions, etc.), and physical habitat assessments for both in-stream and riparian corridor conditions. As of 2012, over 1300 unique perennial stream sites have been monitored by PSA and its partner programs.[1] In 2015, the PSA developed a management memorandum summarizing biological conditions (based on California Stream Condition Index score) and associated stressor data collected at probabilistic sites over a 13-year time period (2000 – 2012) (SWRCB 2015).

The SMC, a coalition of multiple state, federal, and local agencies, initiated a regional monitoring program in 2009. The SMC uses multiple biological indicators to assess ecological health of streams, including BMIs, benthic algae (diatoms and soft algae) and riparian wetland condition. The SMC also collects water chemistry, water column toxicity, and physical habitat data to evaluate potential stressors to biological health. During the first five years of the program (2009 to 2013), the SMC monitored more than 500 probabilistic sites in 15 major watersheds in California's South Coast region, with a focus on perennial streams (Mazor 2015). Evolution of those data suggested that few perennial, wadeable streams in the SMC study area are in good biological condition (Mazor 2015a). Recognizing that perennial streams account for only 25% of stream-miles in the region, in 2015, the SMC expanded its monitoring program to include nonperennial streams, which account for approximately 59% of stream-miles (Mazor 2015b). The SMC program also focused about 30% of the monitoring effort towards revisiting probabilistic sites to provide an estimate of change in condition (Mazor 2015b). The next iteration of the SMC monitoring program will likely include a larger focus on trends monitoring (Rafael Mazor, SCCWRP, personal communication, 2018).

1.4 Biostimulatory/Biointegrity Policy Development

Bioassessment monitoring conducted by the RMC not only provides information about the condition of aquatic life uses in Bay Area streams and how they compare to other regions (i.e., SMC), it also generates a significant baseline dataset that provides context for potential future biological integrity and biostimulatory policies that are currently under development by the State Water Resources Control Board (State Water Board). The biostimulatory policy will likely develop water quality objectives for biostimulatory substances (e.g., nutrients) along with an implementation program as an amendment to the Water Quality Control Plan for Inland Surface Water, Enclosed Bays and Estuaries of California (ISWEBE Plan).[2] The biostimulatory substances policy may include a numeric and/or narrative objective(s) that will be applicable to streams in California. The State Water Board plans is expected to establish the implementation plan for the biostimulatory substances policy in three phases, with each phase including a plan that would be unique for each of the three different water body types. The first phase of the Biostimulatory Amendment would be applicable to wadeable streams.

The biostimulatory policy will also include a water quality control policy (i.e., Biointegrity Policy) to establish and implement biological condition assessment methods, scoring tools, and targets aimed at protecting the biological integrity in wadeable streams. The policy will utilize a multi-indicator approach that includes the California Stream Condition Index (CSCI) for benthic macroinvertebrates and statewide

[1] The Stormwater Monitoring Coalition has collected a majority of samples at probabilistic sites in Coastal Southern California watersheds and the US Forest Service has collected PSA-comparable data from sites in National Forests of the Sierra Nevada.

[2] Information obtained from: https://www.waterboards.ca.gov/water_issues/programs/biostimulatory_substances_biointegrity

algal stream condition index (ACSI), which is currently under development. The State Water Board's plan is to establish "assessment endpoints" as primary lines of evidence to assess beneficial use support in wadeable streams. These endpoints may be used to establish default nutrient objectives or thresholds for California streams, with potential option to refine the thresholds under a "watershed approach."

The State Water Board's biostimulatory/biointegrity project has been delayed due to several unresolved policy issues that need to be addressed prior to development of the policy, including[3]:

1) Consideration of channels in highly developed landscapes (i.e., where assessment endpoints may not be achieved);
2) Identify Beneficial Uses;
3) Relationship between established biological assessment endpoints and nutrient endpoints; and
4) Define process for coordinated watershed approach.

The State Water Board is currently planning to develop draft policy options to present to Stakeholder Advisory and Regulatory Groups in 2019.

[3] Information obtained from presentation by Jessie Maxfield, California State Water Board, given at the 2017 California Aquatic Bioassessment Workgroup conference in Davis, California.

2 METHODS

2.1 STUDY AREA

The study area for RMC creek status monitoring consists of the perennial and non-perennial streams, channels and rivers within the portions of the five participating counties (San Mateo, Santa Clara, Alameda, Contra Costa, Solano) that overlap with the San Francisco Bay Regional Water Quality Control Board (Region 2) boundary, and the eastern portion of Contra Costa County that drains to the Central Valley region (Region 5). The RMC creek status sample frame consists of the urban and non-urban portions of the stream network flowing through the RMC area. The source dataset used to create the sample frame was the 1:100,000 National Hydrography Dataset (NHD).

2.2 SURVEY DESIGN AND SAMPLING SITES

Creek status monitoring sites were selected based on a probabilistic survey design consisting of a master draw of 5,740 sites (approximately one site for every stream kilometer in the sample frame). The selection procedure employed the U.S. EPA's Generalized Random Tessellation Stratified (GRTS) survey design methodology (Stevens and Olson, 2004). The GRTS approach generated a spatially-balanced distribution of sites covering the majority of the San Francisco Bay Area. It should be noted that the sample draw of 5,740 sites did not account for land use designations or other emphases (i.e., County) and therefore, the master draw of sample sites was weighted towards commonly occurring conditions (i.e., non-urban sites), with less common conditions (i.e., reference and urban sites) being less represented due to their lower relative abundance in the sample frame.

The RMC sampling design targeted the population of accessible streams with flow conditions suitable for sampling (i.e., adequate flow during spring index period). A random set of potential monitoring sites (i.e., the master draw) was established, with each site having an equal, non-zero weight, proportional to the inverse of its selection probability. Thus, all sites were assumed to have an equal probability of selection throughout the sample frame. The weights represent the amount of stream length encompassed by each site in the overall target population.

Once the master draw was established, the list of monitoring sites was separated into 19 categories to facilitate site evaluations and implement creek status monitoring, including bioassessment (Table 1). The following attributes were used to generate the categories:

- County (n=5): San Mateo, Santa Clara, Alameda, Contra Costa, Solano (source: California Department of Forestry and Fire, 2009);
- Water Quality Control Board Region (n=2): Region 2, Region 5 (source: San Francisco Regional Water Quality Control Board, undated);
- Land use Category (n = 4): Urban or nonurban in all counties, except Solano ('urban_V' and 'urban_FS' in Solano County). Urban land use was defined as a combination of US Census (2000) areas classified as urban, and areas within Census City boundaries. This definition of urban land use results in some relatively undeveloped areas and parks along the fringes of cities to be

classified as urban. Urban sites therefore represent a broad range of developed (i.e., impervious surface) conditions. Non-urban area was defined as all remaining area in the RMC boundary not classified as urban.

Table 1. Number of sites and stream length from the master draw in each post-stratification category.

County	Urban		Non-Urban		Total	
	Sites	Stream Length (km)	Sites	Stream Length (km)	Sites	Stream Length (km)
San Mateo	222	233.8	528	556.0	750	789.8
Santa Clara	542	570.8	1376	1449.1	1918	2019.8
Alameda	454	478.1	842	886.7	1296	1364.8
Contra Costa (Region 2)	587	618.2	363	382.3	845	889.9
Contra Costa (Region 5)			349	367.5	454	478.1
Solano (Vallejo)	12	12.6	386	406.5	477	502.3
Solano (Fairfield-Suisun)	79	83.2				
				Overall Total	**5740**	**6,044.7**

To maintain a spatially-balanced pool of monitoring sites, sites were evaluated in the order that they appeared in the master draw list (with a few exceptions). Sites were evaluated for sampling using both desktop and field reconnaissance. Field crews attempted to locate a reach suitable for sampling within 300 m of the target coordinates. Sites without a suitable reach were rejected for sampling. Reasons for rejection included physical barriers, lack of flowing water, refusal or lack of response from landowners, unwadeable (i.e., >1 m deep for at least 50% of the reach) and inappropriate waterbody types (e.g., tidally influenced). Sites with temporary inaccessibility, unsafe/hazardous or permission issues (e.g., construction, lack of response from landowners) were re-evaluated for sampling in subsequent years. All program participants were instructed to use a standard set of codes to identify the reason behind exclusion of sites.

In contrast to the PSA and SMC regional monitoring designs, which targeted perennial streams, the RMC sampled both perennial and non-perennial streams. Additionally, at the outset, each countywide Program agreed they would attempt to assess up to 20% of their required sites in non-urban areas.

2.3 Sampling Protocols/Data Collection

Biological sample collection and processing was consistent with the BASMAA RMC Quality Assurance Project Plan (QAPP)[4] (BASMAA 2016a) and Standard Operating Protocols (SOPs) (BASMAA 2016b) which

[4] The RMC QAPP and SOP documents were initially developed in 2012 (Version 1.0), revised in 2013 (Version 2.0) and 2016 (Version 3.0)

were developed to be consistent with the current SWAMP Quality Assurance Program Plan (QAPrP) and SOPs. Bioassessments were conducted during the spring index period (approximately April 15 – June 30) with the goal to sample a minimum of 30 days after any significant storm (defined as at least 0.5-inch of rainfall within a 24-hour period). A 30-day grace period allows diatom and soft algae communities to recover from peak flows that may scour benthic algae from the bottom of the stream channel.

2.3.1 Biological Indicators

Each monitoring site consisted of an approximately 150-meter stream reach that was divided into 11 equidistant transects placed perpendicular to the direction of flow. Benthic macroinvertebrate (BMI) and algae (i.e., diatom and soft algae) samples were collected at each transect using the Reach-wide Benthos (RWB) method described in Ode et al. (2016). The algae composite sample was also used to collect chlorophyll a and ash free dry mass (AFDM) samples following methods described in Ode et al. (2016).

Biological samples were sent to laboratories for analysis. The laboratory analytical methods used for BMIs followed Woodward et al. (2012), using the Southwest Association of Freshwater Invertebrate Taxonomists (SAFIT) Level 1a Standard Taxonomic Level of Effort, with the additional effort of identifying chironomids (midges) to subfamily/tribe instead of family (Chironomidae). Soft algae and diatom samples were analyzed following SWAMP protocols (Stancheva et al. 2015). The taxonomic resolution for all data was standardized to the SWAMP master taxonomic list.

2.3.2 Physical Habitat

Both quantitative and qualitative measurements of physical habitat structure were taken at each of the 11 transects and 10 inter-transects at each monitoring site. At the outset of the monitoring program in 2012, Physical habitat measurements followed procedures defined in the "BASIC" level of effort (Ode 2007), with the following exceptions as defined in the "FULL level of effort: stream depth and pebble count + coarse particulate organic matter (CPOM), cobble embeddedness, and discharge measurements. In 2016, the entire "FULL" level of effort for the characterization of physical habitat described in Ode et al. (2016) was adopted, consistent with the reissued MRP 2.0 (SFBRWQCB 2015). Physical habitat measurements include channel morphology (e.g., channel width and depth), habitat features (e.g., substrate size, algal cover, flow types, and in-stream habitat diversity) and human disturbance in the riparian zone (e.g., presence of buildings, roads, vegetation management). In addition, a qualitative Physical Habitat Assessment (PHAB) score was assessed for the entire bioassessment reach. The PHAB score is composed of three characteristics for the reach, including channel alteration, epifaunal substrate, and sediment deposition. Each attribute is individually scored on a scale of 0 to 20, with a score of 20 representing good condition.

2.3.3 Water Quality

Immediately prior to biological and physical habitat data collection, general water quality parameters (dissolved oxygen, pH, specific conductance and temperature) were measured at each site, at or near the centroid of the stream flow using pre-calibrated multi-parameter probes. In addition, water samples were collected for nutrients and conventional analytes analysis using the Standard Grab Sample Collection Method as described in SOP FS-2 (BASMAA 2016b).

2.3.4 Stressor Variables

Physical habitat, land-use, and water quality data were compiled and evaluated as potential stressor variables for biological condition. Land-use variables were calculated in GIS by overlaying the drainage area for sample locations with land use and road data. The variables included percent urbanization, percent impervious, total number of road crossings and road density at three different spatial scales (1 km, 5 km, and entire watershed).

Physical habitat metrics were calculated using the SWAMP Bioassessment Reporting Module (SWAMP RM). The SWAMP RM output includes calculations based on parameters that are measured using EPA's Environmental Monitoring and Assessment Program (EMAP) for freshwater wadeable streams (Kaufmann et al. 1999), as well as parameters collected under the SWAMP protocol (Marco Sigala, personal communication, 2017). The RM produces a total of 176 different metrics based on data collected using the SWAMP "FULL" habitat protocol. Ten of the best performing metrics (Andy Rehn, CDFW, personal communication) were selected based on best professional judgment from the SWAMP RM output to analyze physical habitat data collected by the RMC.

General water quality (e.g., DO, SpCond) and chemistry (e.g., nitrate and phosphorus) data collected at the bioassessment sites were also included. Some of the water chemistry variables were calculated from the analytes that were measured. These include Total Nitrogen (sum of Nitrate, Nitrite and Total Kjeldahl Nitrogen) and Unionized Ammonia (calculated using pH and temperature).

2.3.5 Rainfall Data

For evaluation of trends, a representative rainfall dataset was collated for San Mateo, Santa Clara, Contra Costa, and Alameda counties. The total accumulated rainfall in each water year during the period of 2012-2016 was calculated. The rainfall dataset assembled was derived from: San Jose Airport (Santa Clara), San Francisco Airport (San Mateo), Oakland Airport (Alameda), and Walnut Creek (Contra Costa).

2.4 Data Analyses

All statistical, tabular, and graphical analyses were conducted in R Studio, running R version 3.4.3 (R Core Team 2016). For analyses involving water quality data, censored results (i.e., below the method detection limit) were substituted with 50% of the method detection limit (MDL). Generally, analytical sensitivity was good, with only three variables having > 30% non-detects (Suspended Sediment Concentration, Nitrite, Ammonia). To facilitate use of the data for random forest and relative risk analyses, missing values were subject to an imputation method to fill in data gaps. Seven variables were found to have missing values. Three of these, Suspended Sediment Concentration (SSC), Dissolved Organic Carbon (DOC), and Alkalinity[5], consisted of more than 50 missing values, and were excluded from further analysis. The remaining four variables (Silica, Ash Free Dry Mass, Chlorophyll a, Nitrate) were subject to imputation using the R-package *mice* (van Buuren and Groothuis-Oudshoorn, 2011). In this method, replacement values were randomly selected from the distribution of observed data. Overall, fewer than 25 values were

[5] Suspended Sediment Concentration (SSC), Dissolved Organic Carbon (DOC) and alkalinity were not monitored in 2016, due to the removal of these parameters in Provision C.8.c of the reissued MRP.

imputed for any variable (Silica, n = 24; AFDM, n = 4; Nitrate, n = 1; Chl a, n = 1), and thus their influence on the analysis is assumed to be minor.

2.4.1 Biological Condition Indices

The California Stream Condition Index (CSCI) was developed by the State Water Board as a standardized measure of benthic macroinvertebrate assemblage condition in perennial wadeable rivers and streams. The CSCI was developed using a large reference data set representing the range of natural conditions in California (Ode et al. 2016). The CSCI tool (Mazor et al. 2016) translates BMI data into an overall measure of stream health by combining two types of indices: 1) ratio of observed-to-expected taxa (O/E) (used as a measure of taxonomic completeness), and 2) a predictive multi-metric index (pMMI) for reference conditions (used as a measure of ecological structure and function). The CSCI score is computed as the average of the sum of O/E and pMMI.

The CSCI scoring tool was used to assess BMI data collected at both perennial and non-perennial sites in the RMC area. The CSCI scores for RMC sites should be interpreted with caution, as the CSCI tool has not been fully validated at non-perennial sites. Preliminary analyses suggest that the CSCI is valid in certain types of nonperennial streams in southern California, but its validity in nonperennial streams in other regions, such as the Bay Area, remains unknown.

The algae data were analyzed using algal indices of biological integrity (IBIs) that were developed for streams in Southern California (Fetscher 2014). These include a soft algae index (S2), diatom index (D18) and soft algae-diatom hybrid index (H20). The algal indices were calculated using the SWAMP Algae Reporting Module (Algae RM). The interpretation of algae data collected in San Francisco Bay area using IBIs developed in Southern California (SoCal) should be considered preliminary. The State Board and SCCWRP are currently developing and testing a statewide index using benthic algae data as a measure of biological condition for streams in California. The statewide Algae Stream Condition Indices (ASCIs) were not available at the time this project was conducted, but are expected to be available in late 2018 (personal communication, Jessie Maxfield, SWRCB).

2.4.2 Biological Indicator Thresholds

Existing thresholds for biological indicator scores (CSCI, D18, S2) defined in Mazor (2015) were used to evaluate bioassessment data compiled and analyzed in this report (Table 2, Figure 1). The thresholds for each index were based on the distribution of scores for data collected at reference calibration sites in California (BMI) or in Southern California (algae). Four condition categories are defined by these thresholds: "likely intact" (greater than 30th percentile of calibration reference site scores); "possibly altered" (between the 10th and the 30th percentiles); "likely altered" (between the 1st and 10th percentiles; and "very likely altered" (less than the 1st percentile). The probability-based approach to develop the threshold classes was consistent across indices, allowing comparison for all indicators across sites.

The performance of CSCI on a statewide basis is the subject of ongoing review by the State Water Board. In the current MRP, the SF Bay Water Board defined a CSCI score of 0.795 as a threshold for identifying sites with degraded biological condition that should be considered candidates for Stressor Source Identification (SSID) projects. No MRP threshold has been established for any of the algae indices.

Table 2. Biological condition indices, categories and thresholds.

Index	Likely Intact	Possibly Altered	Likely Altered	Very Likely Altered
Benthic Macroinvertebrates (BMI)				
CSCI Score	≥ 0.92	≥ 0.79 to < 0.92	≥ 0.63 to < 0.79	< 0.63
Benthic Algae				
S2 Score	≥ 60	≥ 47 to < 60	≥ 29 to < 47	< 29
D18 Score	≥ 72	≥ 62 to < 72	≥ 49 to < 62	< 49

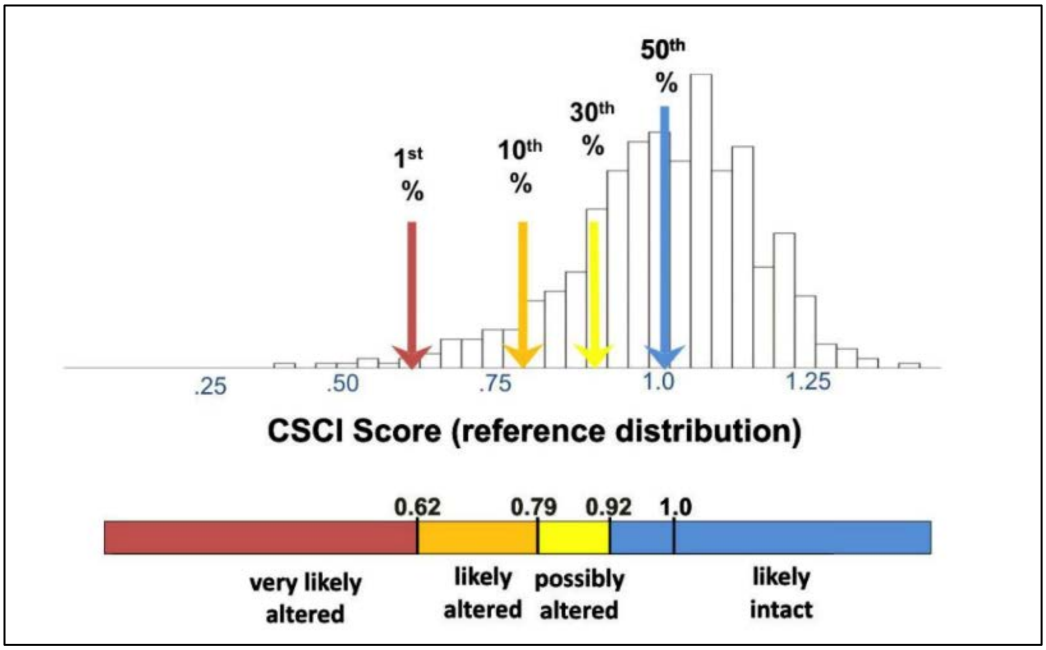

Figure 1. Distribution of CSCI scores at reference sites with thresholds and condition categories used to evaluate CSCI scores (from Rehn et al. 2015). Note: colors in this figure differ from other figures in this report.

2.4.3 Estimating Extent of Healthy Streams in SF Bay Area

To estimate overall extent of biological conditions in streams within the RMC area, cumulative distribution functions (CDFs) of biological condition scores were generated. Because the survey focused significantly more effort in urban areas compared to non-urban areas, sample weights were re-calculated as the total stream length in the sample frame, and divided by the stream length evaluated in each land use category. Therefore, sites contribute a proportional amount of stream length to the extent estimates, based on the number of sites assessed in each land use category. Sites without evaluations (6%), primarily non-urban sites, were excluded from the analysis. The adjusted sample weights were used to estimate the proportion of stream length represented by CSCI, D18, and S2 scores both regionwide and for urban sites only. Estimates for non-urban streams were not calculated separately due to the lower number of monitoring events at non-urban sites and greater width of confidence intervals. Condition estimates and 95% confidence intervals were calculated for all sampled sites in the RMC sample frame and for urban sites only. Post-stratification of the urban sites by County was also performed. However, Solano County was excluded from this assessment, due to the relatively low sample size compared to the other areas. All calculations were conducted using the R-package *spsurvey* (Kincaid and Olsen 2016). See Section 4.4 for further discussion of the RMC sample design.

2.4.4 Evaluating the Importance of Stressors

2.4.4.1 Random Forest Analyses

Stressor association with biological condition scores was evaluated using random forest statistical analyses. Random forest analysis is a non-parametric classification and regression tree (CART) method commonly applied to large datasets of multiple explanatory variables. Recent papers describe their use for stressor identification in stream bioassessment studies (e.g., Maloney et al. 2009, Waite et al. 2012, Mazor et al. 2016). Random forest models use bootstrap averaging to determine splits of numerous trees (Elith et al. 2008) for reducing error and optimizing model predictions. Model outputs provide an ordered list of importance of the explanatory variables that can be applied to a new or validation dataset for prediction.

Random forest models were developed using the R-package *randomForest* to determine a list of explanatory variables related to biological condition scores (CSCI or D18 score). The stressor data consisted of 49 variables, related to (1) water quality; (2) habitat; and (3) land use factors that could potentially influence condition scores (Appendix 1, Table A). Subsequently, the data were partitioned into training (80%) and validation (20%) sets for model testing. A random selection of samples was generated by sub-sampling from within each RMC County to maintain a regional balance of samples within the partitioned datasets. The training dataset had 278 sites, while the validation data encompassed 76 sites across all counties.

First, several iterations of the model procedure were performed with the training data set to optimize the random forests, including tuning the model to the maximum number of predictors per branch, the number of trees to build, and validation of the predictions. Appendix 1 presents the results of initial steps to optimize the random forest model outputs. The final set of models evaluated a maximum of 6 predictor interactions, and 1000 trees. Two variable importance statistics were used to estimate the relative influence of predictor variables: (1) % Increase in MSE = percent increase in mean-square-error of predictions as a result of variable values being permuted; (2) Increase in Node Purity = difference between the residual sum-of-squares before and after a split in the tree. More important variables achieve larger changes in MSE and node purity. K-fold cross validation of the selected models was performed to assess prediction error, by evaluating residual error and R-squared differences.

Random forest models were developed in two steps: (1) random forest models were run with all variables included (N = 49), retaining the top 10 variables in the variable relative importance list ranked by % increase in MSE, and (2) random forest models were re-run with just the top 10 variables from step 1. Subsequently, the variable list was further trimmed by evaluating the corresponding variable importance scores, partial dependency plots, and the change in R^2 once the variable was excluded. Partial dependency plots show the predicted biological response based on an individual explanatory variable with all other variables removed. No variable with less than 10% influence on CSCI or D18 predictions was retained in the final models. Finally, random forest models were used to predict biological condition scores for the validation data set. Appendix 1, Figure B presents the observed and predicted values for the validation models with CSCI and D18 in Steps 1 and 2 of the model development.

2.4.4.2 Stressor Thresholds and Relative Risk Assessment

Relative risk analyses were also conducted to evaluate associations between stressors with biological condition scores. From the list of potential stressors discussed in Section 2.3.4, eight variables were selected to conduct a relative risk analyses (Table 3). Six of the stressor thresholds were derived from statewide data collected for the Perennial Streams Assessment (SWAMP 2015). The thresholds were based on the 90^{th} percentile of data collected at bioassessment sites that exhibited good biological condition (i.e., CSCI scores > 0.92, likely intact). The 90^{th} percentile of stressor values at these sites was used to define the most-disturbed thresholds for variables where higher values indicate more disturbance (SWRCB 2015). Similarly, the chlorophyll a threshold (100 mg/m2) used for this report (Table 3) was based on 90^{th} percentile of data that was collected at all RMC sites that had CSCI scores > 0.92 (Figure 2). The threshold for Dissolved Oxygen (7.0 mg/l) was based on Water Quality Objectives (WQOs) for COLD Freshwater Habitat Beneficial Use in the Water Quality Control Plan for the San Francisco Basin (SFBRWQCB 2017).

Table 3. Biological condition and stressor variable thresholds used for relative risk assessment.

Variables	Thresholds		Units	Reference	Criteria
Biological Condition	*Poor*	*Good*			
CSCI Score	< 0.625	≥ 0.925		Mazor et al. 2016	
Stressor Condition	*High*	*Low*			
Dissolved Oxygen (DO)	<7.0	≥ 7.0	mg/L	SF Bay Water Quality Control Plan	WQO
Specific Conductivity (SpCon)	> 1460	≤ 1460	us/cm	SWAMP 2015	90^{th} Percentile of sites with CSCI score > 0.925
Chloride	> 122	≤ 122	mg/L		
Total Nitrogen (TotN)	> 2.3	≤ 2.3	mg/L		
Total Phosphorus (TotP)	> 0.122	≤ 0.122	mg/L		
Chlorophyll a (Chla)	> 100	≤ 100	mg/m^2	RMC data	
Sand and Fines (SaFn)	> 69	≤ 69	%	SWAMP 2015	
Human Disturbance Index (HDI)	> 1.3	≤ 1.3			

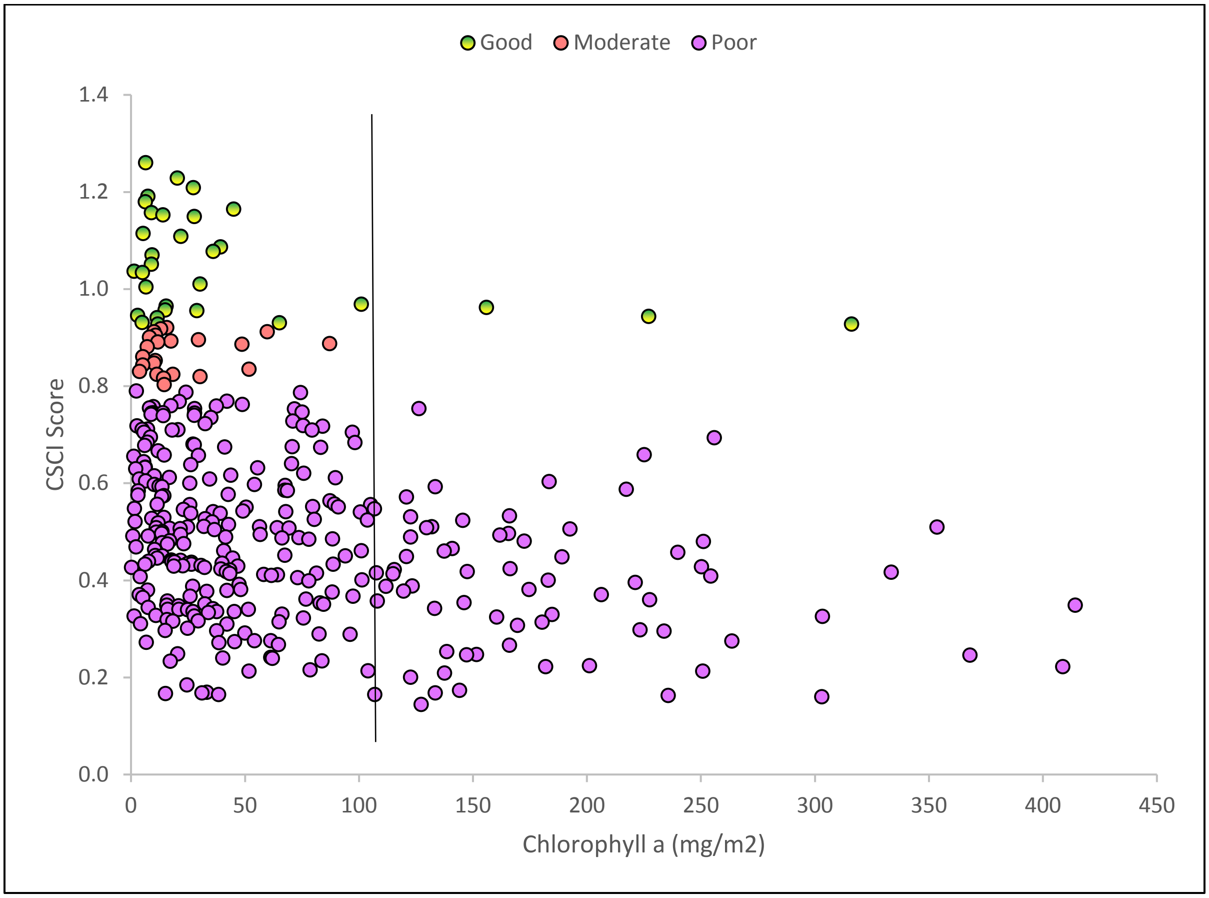

Figure 2. Plot of CSCI score and *chlorophyll a* concentration at RMC sites. Threshold for *chlorophyll a* used for relative risk assessment is shown. Sites classified as "good" include the two highest CSCI condition categories.

The relative risk approach was used to evaluate the association between stressors and biological condition (Van Sickle et al., 2008). The relative risk is a conditional probability representing the likelihood that poor biological condition is associated with high stressor levels and is calculated as follows:

$$\text{Relative Risk} = \frac{\Pr\,(CSCI_p)/S_h}{\Pr\,(CSCI_p)/S_l}$$

The numerator is the probability of finding poor biological condition ($CSCI_p$) given high stressor scores (S_h) and denominator is the probability of finding poor biological condition given low stressor scores (S_l). Poor biological conditions were defined as CSCI scores < 0.625. High and low stressor levels are defined in Table 3. In cases where RR is equal to 1, there is no association between stressor and biological indicator score. Where RR > 1, the higher the value, the more likely poor biological condition would occur given high stressor levels.

3 Results

3.1 Site evaluation results

A total of 354 monitoring sites were sampled in the RMC region between 2012 and 2016. These are identified as “target” sites in Figure 3 and Table 4. Samples were collected at 284 urban sites (80%) and 70 non-urban sites (20%) (Table 4). The greatest number of non-urban sampling locations were in Santa Clara (n=25) and San Mateo Counties (n=19). Samples were collected at 8 or 9 non-urban sites for each of the other counties.

The population of 354 monitored sites was obtained through the evaluation of 1,455 unique sites, which equate to a rejection rate of 76% for entire RMC area over the 5-year period. Solano County had the highest rejection rate (90%) and San Mateo County had the lowest (65%). The most common reason for site rejection (55% of all evaluated sites) was that a site did not present the physical requirements to support monitoring within a 300-meter radius of target coordinates. These “non-target sites” were rejected for several reasons, including lack of flowing water, site was not a stream (e.g., aqueduct or pipeline), tidally influenced, or non-wadeable. The lack of flow was the most common reason for rejection. The extended drought period between 2012 and 2014 may have resulted in an unusually high number of sites with no or low flow conditions during the target index period.

Another reason for site rejection was the inability to obtain access to conduct the sampling (e.g., physical access or obtain private land/permission). These “target non-sampleable” sites comprised 21% of sites that were rejected. These sites were often located on private land in non-urban areas where permissions were not granted and/or where steep, highly-vegetated conditions prevented access. Obtaining access to sites in urban areas was variable by county. For example, most of the streams in the urban area of San Mateo County are privately owned, while most of the urban sites in Santa Clara County are owned by municipal jurisdictions and water district agencies, making permissions more easily obtained.

Table 4. Number of sites per county in each site evaluation class.

County	Target Not-Sampleable		Non-Target		Target		Total by County
	Non-Urban	Urban	Non- Urban	Urban	Non- Urban	Urban	
Alameda	12	74	162	91	9	96	444
Contra Costa	12	34	32	89	9	48	224
San Mateo	21	42	9	37	19	41	169
Santa Clara	37	24	74	161	25	87	408
Solano	44	3	109	34	8	12	210
Total RMC	126	177	386	412	70	284	1,455
% of Total RMC	9%	12%	27%	28%	5%	20%	-

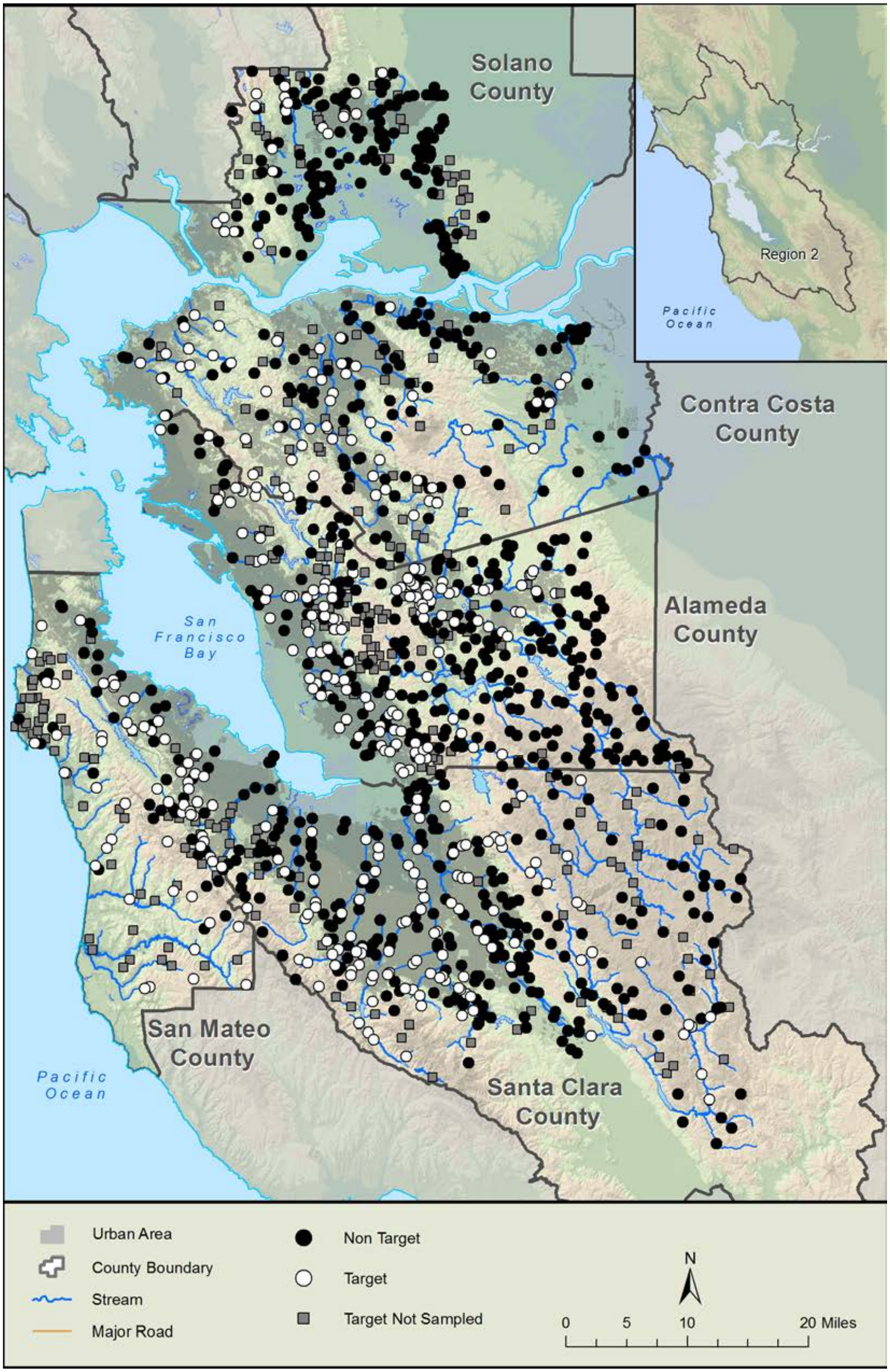

Figure 3. RMC sites evaluated by evaluation class.

Figure 4 presents rainfall for the 2000-2017 time period at the San Francisco Airport. Rainfall was generally below average during the 2012-2016 period, especially in 2014, and therefore, the RMC monitoring occurred in a drier-than-normal period. Because biological condition index scores can vary natural due to multi-year climatic patterns, it is important to note that the 5-year period of monitoring may not be representative of the long-term condition.

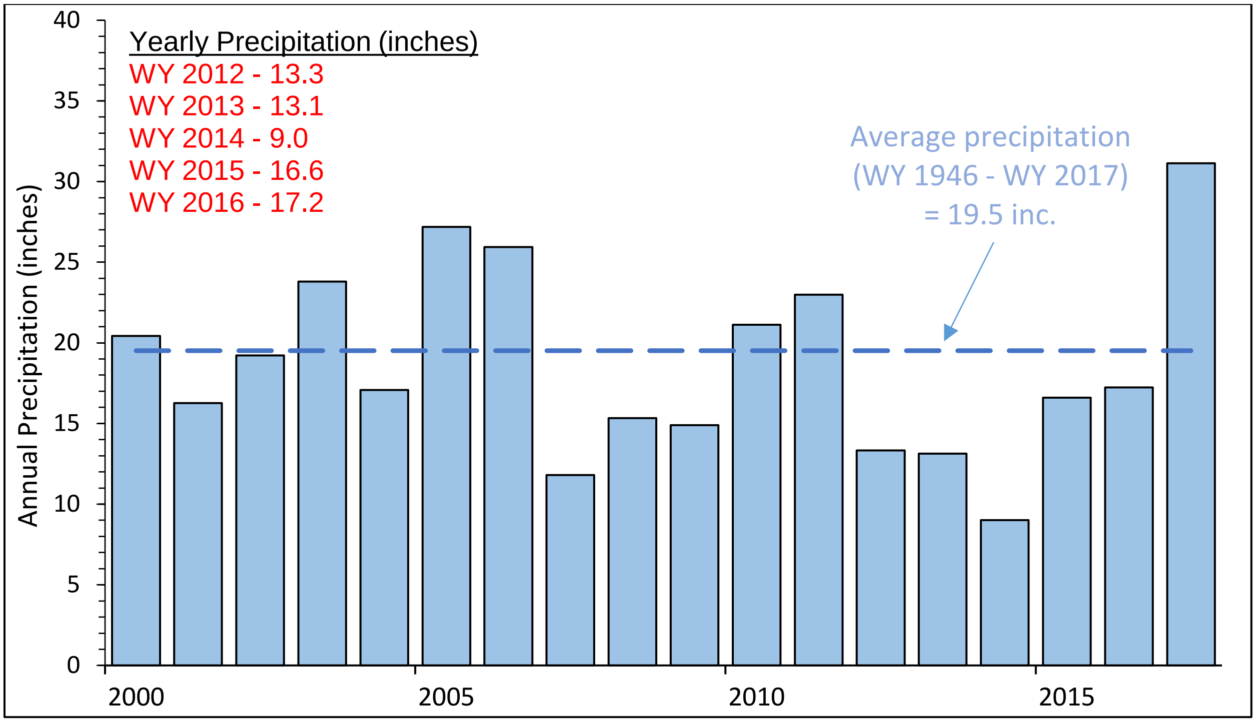

Figure 4. Annual precipitation at San Francisco Airport (2000-2017)

3.2 Biological Condition of Bay Area Streams

3.2.1 Regional Assessment

The distribution of BMI and algae index scores observed during 2012-2016 suggests that the majority of streams in the RMC sample area do not exhibit healthy biological conditions. Figures 5, 6 and 7 show cumulative distribution functions of the biological index scores for the entire regional dataset (i.e., urban and non-urban sites) and the urban dataset. Across all sites, over half (58%) of the stream-length was in the lowest condition class for CSCI (Very Likely Altered) and 15% of the stream-length was in the highest condition class (Likely Intact) (Figure 5).

Both of the algae index scores (D18 and S2) exhibited higher condition scores than CSCI regionally. For D18 (diatoms), 41% of the stream-length in the Bay Area was in the Very Likely Altered condition class and 19% of the stream-length was in the Likely Intact condition class (Figure 6). Similar distribution of scores was evident with S2 (soft-algae), where less than half (44%) of the stream-length was in the Very Likely Altered condition class and 21% of the stream-length was in the Likely Intact condition class (Figure 7). The higher proportion of sites in the Likely Intact condition for algae indices compared to CSCI suggest that the algae communities in streams may be less degraded than BMI assemblages.

Bay Area wide, urban sites were responsible for the majority of poor CSCI scores. Seventy-nine percent (79%) of the stream length in urban areas was in the Very Likely Altered condition category for CSCI, while only 3.5% was in the Likely Intact class (Figure 5). Additionally, over 80% of the sampled stream length in urban areas was below the MRP trigger for CSCI scores (0.795), where potential follow-up source/stressor identification studies should be considered.

The influence of urban sites on the stream condition of all sites was also apparent for algae scores, although to a lesser degree than for CSCI. For D18, just over half (53%) of the stream length in urban areas was in the Very Likely Altered condition class, compared to 9% in the Likely Intact class (Figure 6). For S2 scores, 65% of stream length in urban areas was in the Very Likely Altered class, and only 7% in the Likely Intact class (Figure 7). These patterns suggest that stressors in the urban landscape may still exert influence on algae condition. Section 4.0 provides additional discussion about the results presented here.

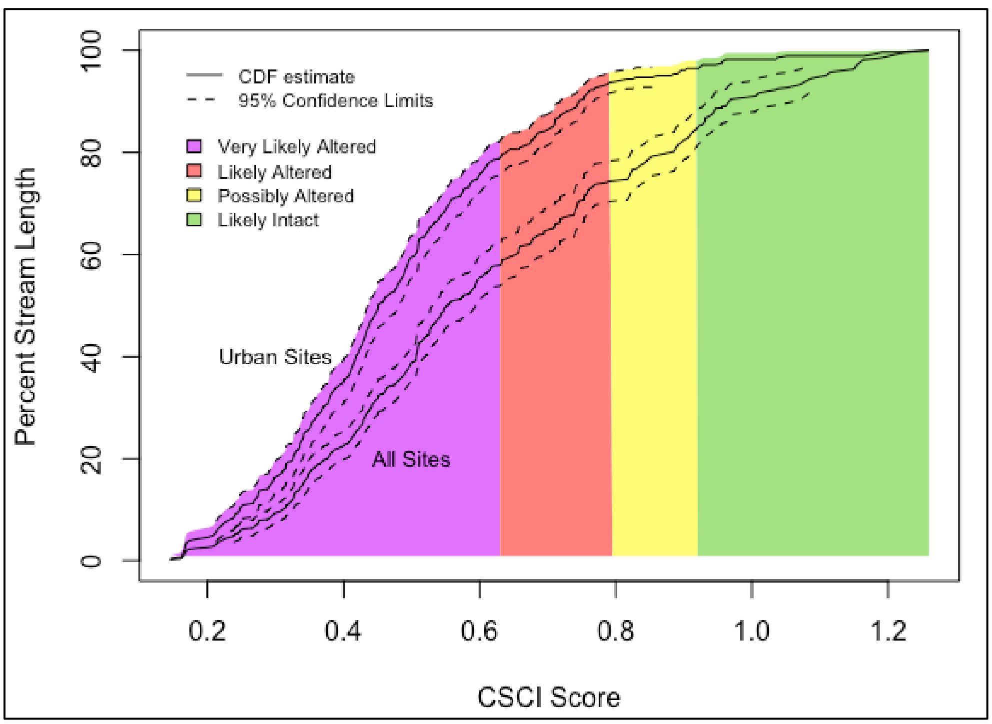

Figure 5. Cumulative distribution function (CDF) of CSCI scores at all RMC sites and urban sites.

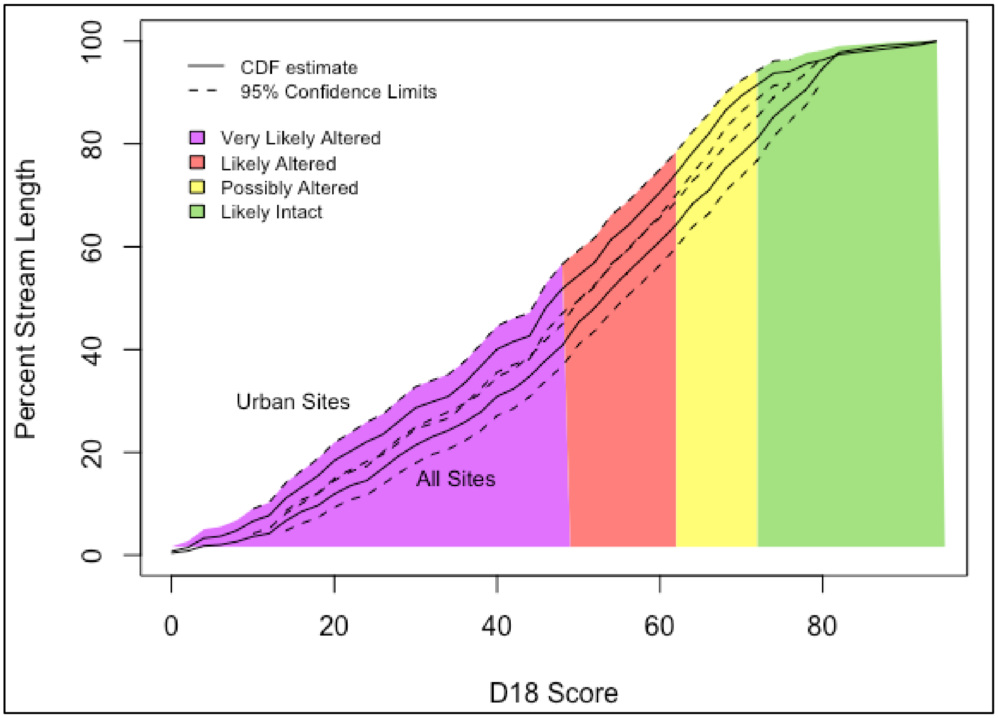

Figure 6. Cumulative distribution function (CDF) of D18 scores at all RMC sites and urban sites.

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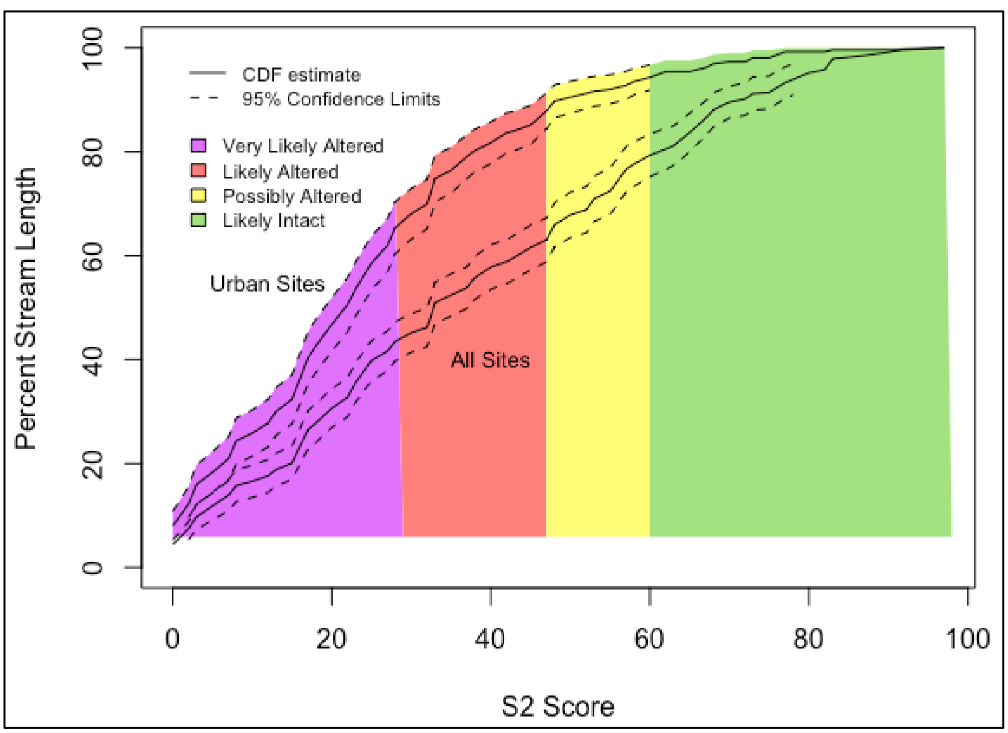

Figure 7. Cumulative distribution function (CDF) of S2 scores at all RMC sites and urban sites.

3.2.2 County Assessment

In addition to Bay Area wide biological condition estimates of streams, post-stratification of the CSCI condition estimates for urban sites in each County (excluding Solano County due to low sample size) suggests that poor condition scores are widespread in each Bay Area county. The proportion of urban stream length in the Very Likely Altered condition class was highest for Contra Costa (96%), followed by Alameda County (83%), San Mateo County (73%), and Santa Clara County (64%) (Figure 8). Less than 10% of the urban stream length in each of the counties was in the Likely Intact condition class. The highest proportion of Likely Intact BMI communities occurred in San Mateo and Santa Clara counties (7% each), followed by Alameda (1%) and Contra Costa (0%) counties. In comparison to the MRP threshold of 0.795, the vast majority of urban streams in each county fall below this threshold.

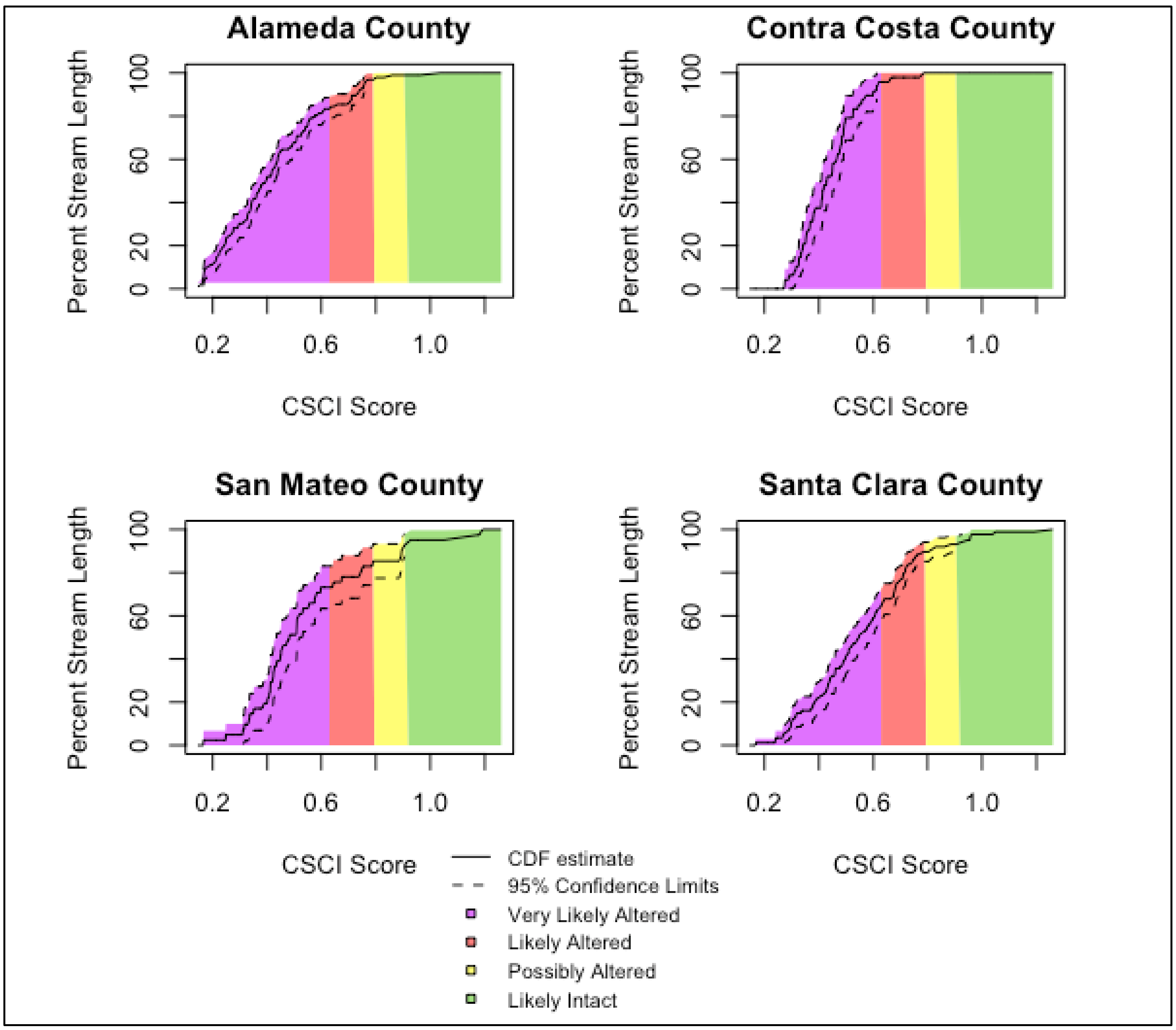

Figure 8. Cumulative distribution functions of CSCI scores at RMC urban sites in each participating Bay Area County.

3.2.3 Biological Condition of Urban and Non-Urban Streams

Figure 9 illustrates CSCI scores (by condition category) for the region and includes county boundaries and urban areas for reference. Maps illustrating the biological condition of stream in each county based on CSCI and D18 scores are included in Appendix 4.

Figure 9. Biological condition of streams in the RMC area based on CSCI scores.

CSCI scores grouped by land use class (urban vs. non-urban) showed that all counties, with the exception of Solano, exhibit higher scores in non-urban areas (Figure 10), which generally span a narrower scoring range than urban sites. Santa Clara and San Mateo counties had the highest median CSCI scores compared to other counties, with several sites in both counties receiving scores greater than 1.0, which typically represent reference conditions. However, non-urban sites for all five counties had CSCI scores below the MRP trigger (0.795), indicating that some sites non-urban areas have degraded biological condition.

Stratification of D18 and S2 scores by land use (urban vs non-urban; Figures 11 and 12) suggests that biological condition scores based on algae metrics generally mirror CSCI scores, which are based on BMIs. Generally, algae scores in the non-urban area were higher than scores for sites in urban areas within each county. The low sample sizes of the non-urban population preclude making any definitive comparisons, however, it was noteworthy that sites in the urban areas may receive similar or higher algae index scores than sites non-urban areas.

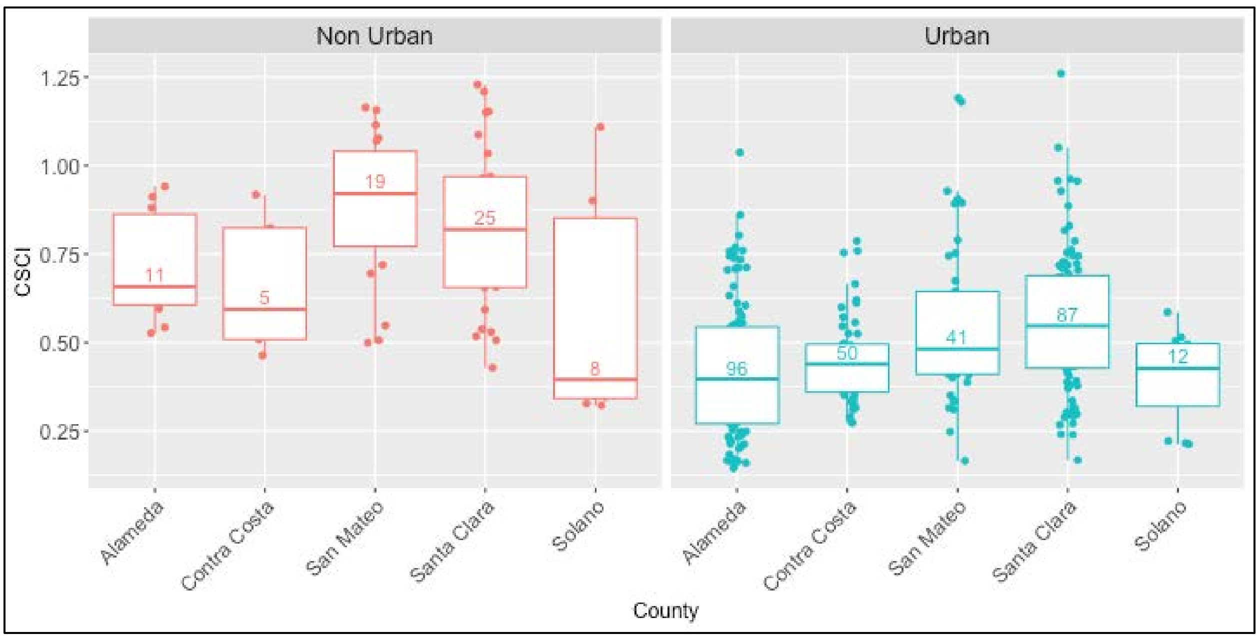

Figure 10. CSCI scores for urban and non-urban sites in each County. Sample sizes for each county are included in each boxplot.

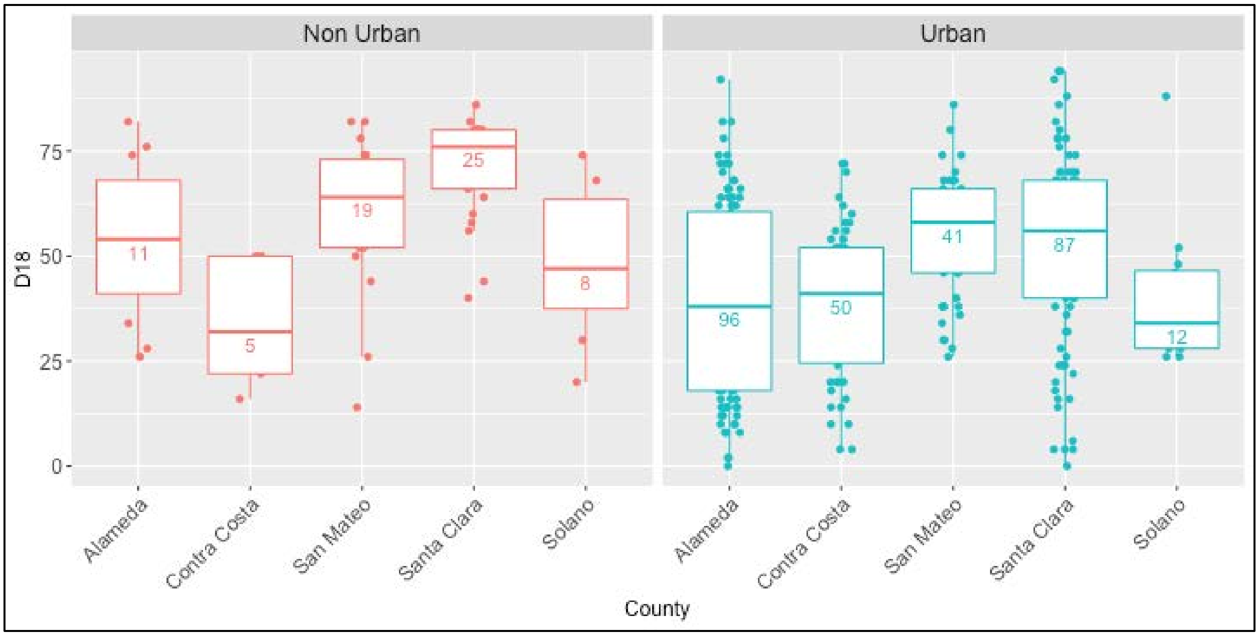

Figure 11. D18 scores for urban and non-urban sites in each County. Sample sizes for each county are included in each boxplot.

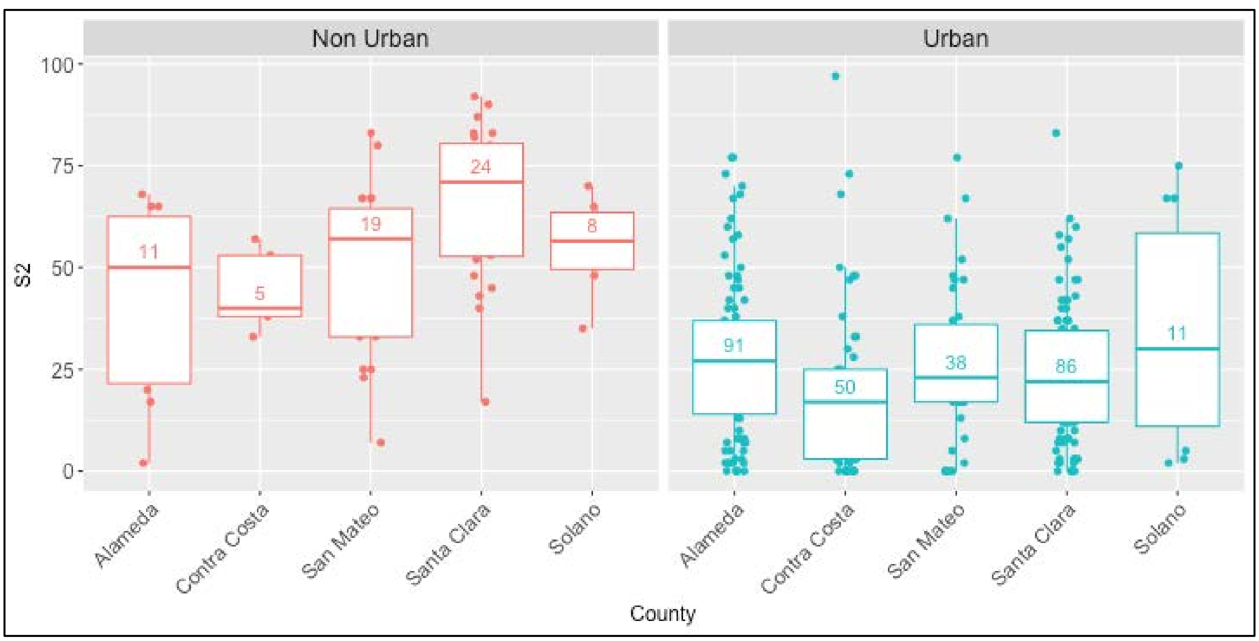

Figure 12. S2 scores for urban and non-urban sites in each County. Sample sizes for each county are included in each boxplot.

3.3 Stressors Associated with Biological Condition

3.3.1 Random Forest Model Outputs

To evaluate stressors associated with biological condition within the RMC area, random forest models were developed using the CSCI and D18 index results. A parallel analysis was not performed for the S2 indicator due to the lack of soft algae at many of the assessment sites. Stressor data consisted of 49 variables grouped into three types: (1) water quality; (2) habitat; and (3) land use (Appendix 1, Table A). Model results clearly indicated better relationships between stressors and the CSCI, versus the D18 index. Validation of the final random forest models showed that the CSCI model explained 61% of the variance using eight predictor (stressor) variables, while the D18 model only explained 34% of the variance using six predictors.

The CSCI random forest model indicated that land use and physical habitat variables were most influential to most biological condition (Table 5). Of the eight variables in the final CSCI model, four were landscape-based (HDI, PctImp_5K, PctImp_1K, PctImp), three were habitat associated (PctFines, PctGra, PctFstH20), and one was a water quality variable (Dissolved Oxygen, DO). There was general consistency amongst the individual variables within each of the landscape and habitat groups. The landscape variables that were most influential to CSCI scores were associated with the degree of human impact/imperviousness and the habitat variables were associated with the characteristics of the sediment substrate and water flow. Overall, the largest influence on the CSCI random forest model was percent impervious area within a 5 km radius (35.2%) of the site. The other seven variables in the final model exerted a lesser, but similar degree of influence (18.8 – 25.3%) on CSCI scores. It was notable that none of the nutrient variables were identified as indicators of biological condition scores using the CSCI model (Appendix 3 Figure A). The same may be true for DO, where the apparent relationship was driven by a few high values (Appendix 3 Figure B).

Table 5. Summary statistics for the CSCI random forest model. Rank of importance of selected stressor variables are colored according to categories: physical habitat (green), land use (brown), and water quality (blue). The correlation coefficient (rho) for each stressor variable is also presented.

Stressor Variable	% Increase MSE	Increase Node Purity	Rank Correlation Coefficient (Rho)
Percent Impervious Area in 5km (PctImp_5K)	35.21	4.74	-0.62
Percent Impervious Areas of Reach (PctImp)	25.37	1.03	-0.59
Dissolved Oxygen (DO)	24.43	1.60	0.24
Percent Fast Water of Reach (PctFstH20)	22.52	1.62	0.51
Percent Fines (PctFin)	20.73	1.13	-0.36
Percent Substrate Smaller than Sand (PctSmalSnd)	20.64	1.36	-0.46
Percent Impervious Area in 1km (PctImp_1K)	20.64	2.26	-0.61
Human disturbance Index (HDI)	18.81	1.45	-0.62

The results of the random forest model for D18 indicated that different variables explained biological condition than the CSCI model. Water quality variables exerted greater influence in the D18 model (Table 6). Of the six variables in the final D18 model, four were water quality variables (SpCond, Chloride, AFDM, Phosphorus), one was a habitat variable (PctSmalSnd), and one was a landscape variable (RdDen_1k). Overall, the variable with the largest influence on the random forest model was specific conductivity (29.5%). The remaining five variables exerted a lesser, but similar influence (12.5% – 22.0%) on the model. The importance of water quality variables in the model suggests that general water quality conditions (e.g., conductivity) likely influence algae condition scores. Specific types of water quality stress, such as from nutrients, however, appear to be less important to algal community condition on a regionwide scale.

Table 6. Summary statistics for the D18 random forest model. Rank of importance of selected stressor variables are colored according to categories: physical habitat (green), land use (brown), and water quality (blue). The correlation coefficient (rho) for each stressor variable is also presented.

Stressor Variable	% Increase MSE	Increase Node Purity	Rank Correlation Coefficient (Rho)
Specific Conductivity (SpCond)	29.55	35357.81	-0.49
Percent Substrate Smaller than Sand (PctSmalSnd)	21.99	24671.80	-0.46
Phosphorus	21.93	17465.87	-0.33
Chloride	18.53	18873.52	-0.51
Ash Free Dry Mass (AFDM)	15.09	21937.23	-0.44
Road Density in 1km (RdDen_1k)	12.51	16383.17	-0.33

Using the random forest model outputs, plots of individual stressor variables versus observed response values (i.e., CSCI and D18 scores) were developed to illustrate relationships between stressors and biological condition (Figures 13 to 18 and Appendix 2). For the CSCI model output, the plots of habitat and landscape variables indicate patterns of dose-response. For example, the Human Disturbance Index (HDI) stressor variable indicated that poor condition scores are observed when HDI exceeds a value of 2. This pattern was also evident in the regressions of observed CSCI values, relative to HDI and separating out HDI scores by their condition class (Figure 13). It is worth noting that Ode et al. (2016) identified a cutoff of HDI = 1.5 for reference sites (Ode et al. 2016). Based on the analysis conducted on this five-year Bay Area dataset, the range between 1.5 and 2.0 appeared to separate out the urban and non-urban sites, supporting the previous authors' assertion that sites with HDI values below this range exhibit reference conditions.

Similar to HDI, the stressor variables related to imperviousness indicated a threshold-style response with CSCI scores. For the variable 'percent imperviousness in 5km', a value above 10% appeared to correspond to poor CSCI condition scores (Figure 14). All sites that had less than 10% impervious area within 5km were classed as either Possibly Intact or Likely Intact condition. In the case of the habitat variables included in the final model, response patterns were less pronounced than for the landscape variables (Figure 15). For example, the variable 'percent reach habitat smaller than sand', indicated that poor sites spanned a wide-range in stressor values, while sites in the top three condition classes had a much narrower range in this metric. Biological condition at sites where more than 50% of the stream reach had substrate smaller than sand appeared to be a line of demarcation between the bottom two and top three condition categories.

The results of the D18 model indicated dose-response relationships between biological condition and all four water quality variables (i.e. SpCond, Chloride, AFDM, Phosphorus), however there were less obvious patterns delineating biological condition. For example, the partial dependency plots for D18 scores indicated that poor condition (i.e., bottom two condition categories) was evident when chloride was above 200 mg/L (Figure 16) and specific conductivity was above 1200 µS/cm[6] (Figure 17). However, the plots of observed D18 values relative to these variables suggested that only some of the lowest scoring sites could be delineated using these threshold values. Similarly, response patterns of the habitat variables were inconclusive for delineating biological condition. A value of approximately 60% or greater of the stream habitat ‘smaller than sand’ corresponded to lower D18 scores (Figure 18), but there was considerable variability to this signal.

[6] This corresponds well with the MRP threshold of 2000 uS/cm^2 for evaluating continuous monitoring data. Sites with 20% or more of instantaneous specific conductance results greater than 2000 uS/cm^2 are considered as candidates for SSID projects.

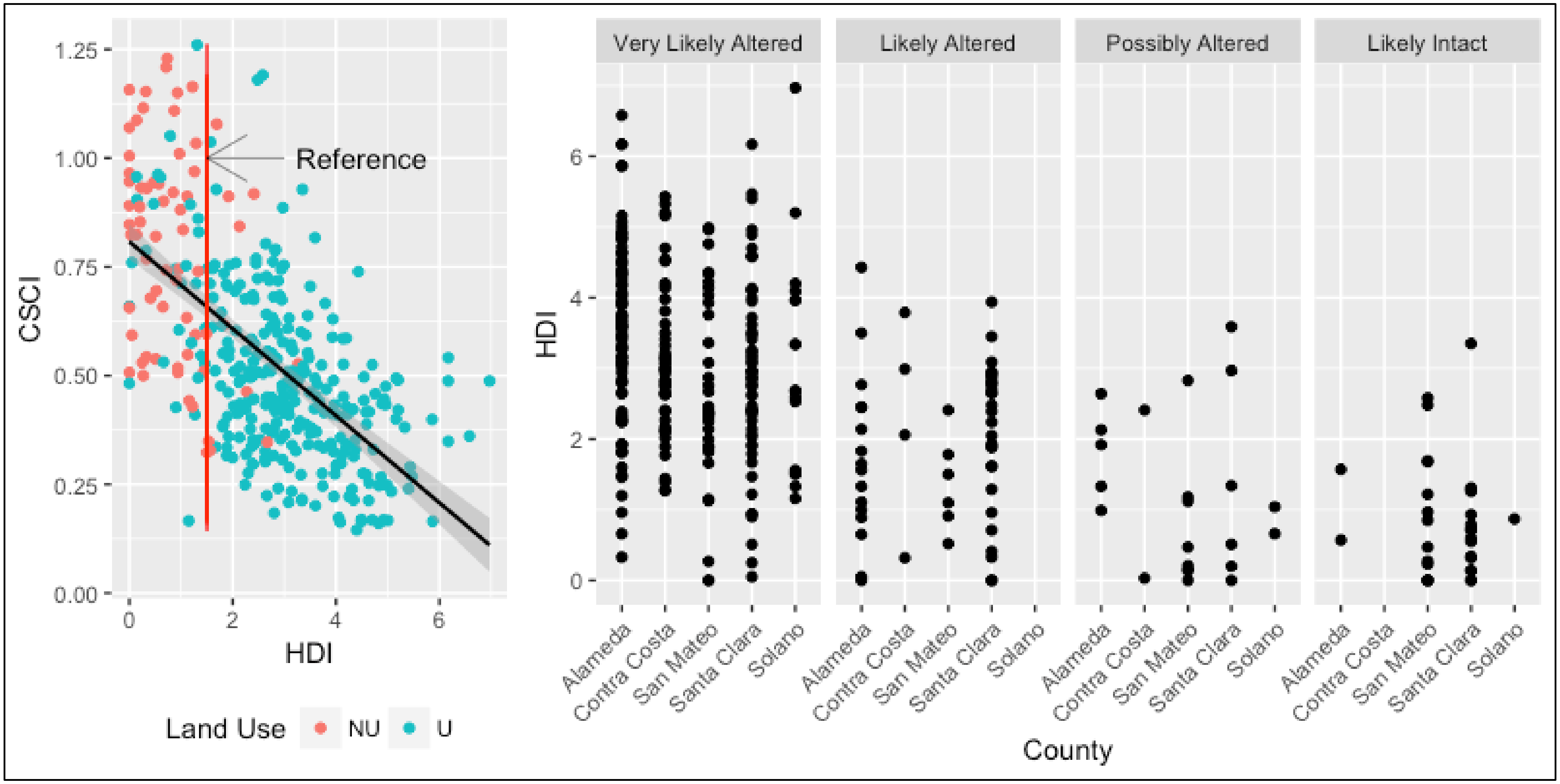

Figure 13. Relationship of CSCI scores to the Human Disturbance Index (HDI) stressor indicator. Red line indicates a reference condition cutoff of 1.5 (Ode et al. 2016).

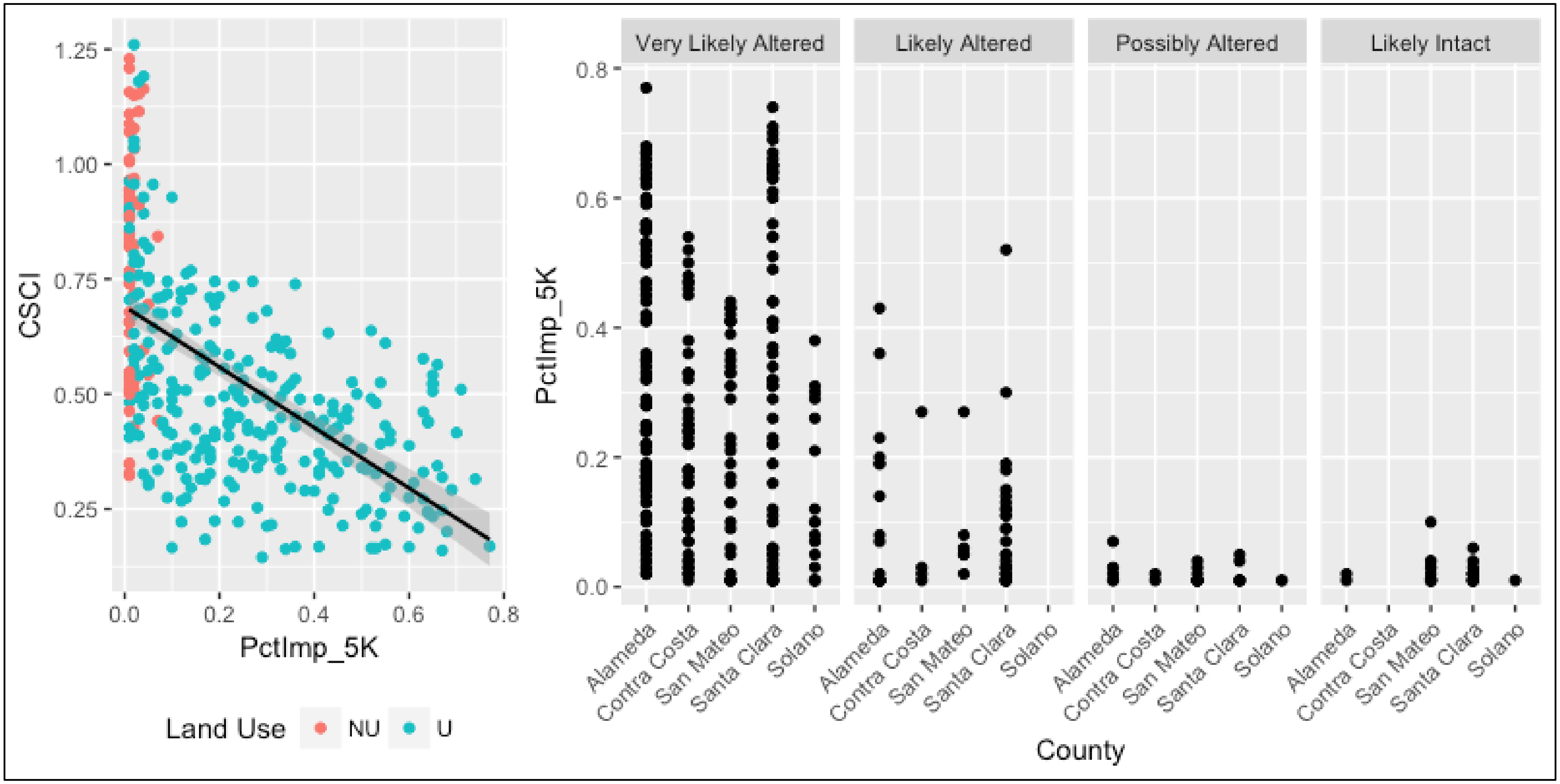

Figure 14. Relationship of CSCI scores to the percentage of land area in a 5 km radius (km²) around the site that is impervious.

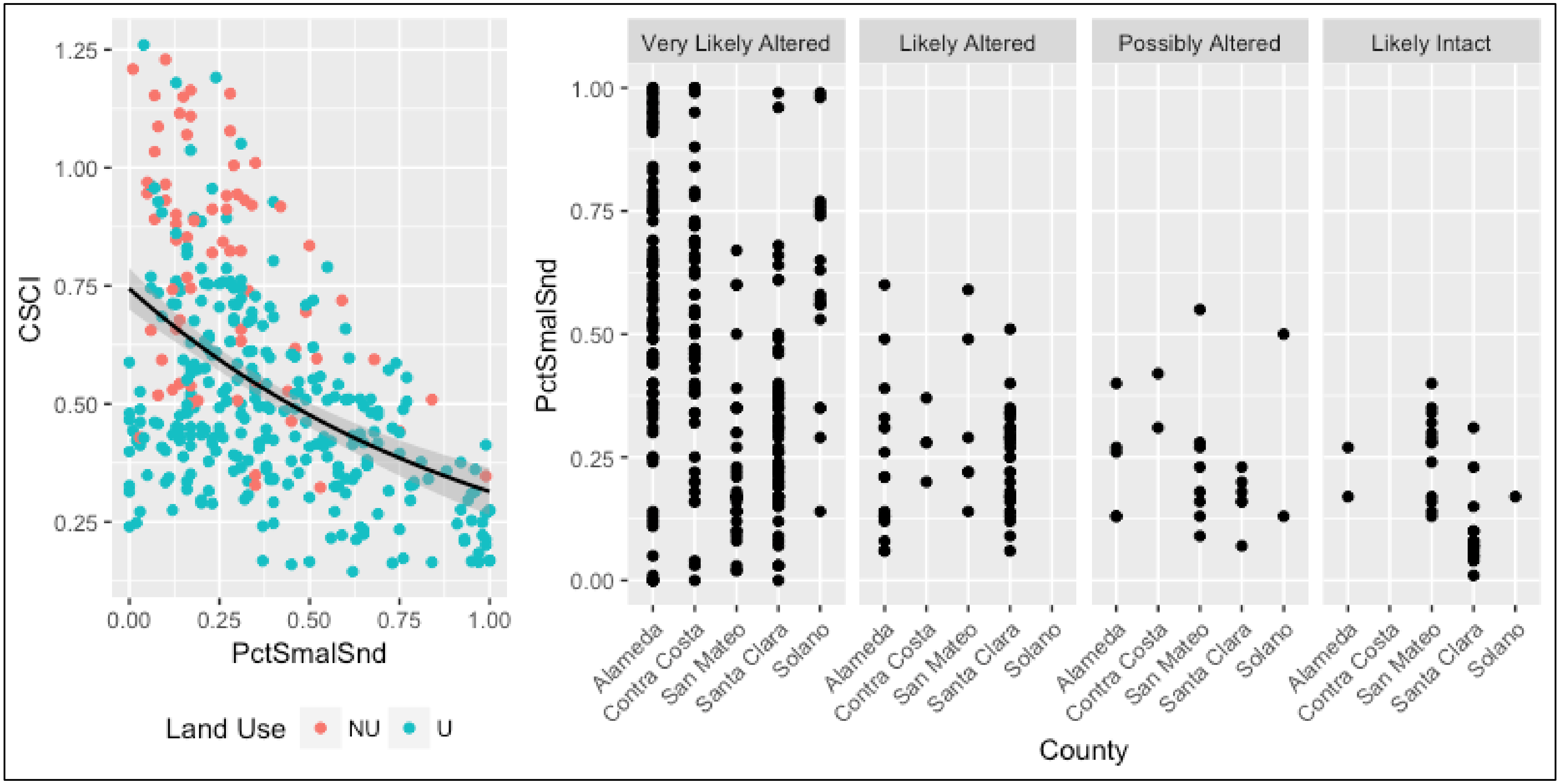

Figure 15. Relationship of CSCI score to the percent of substrate in the stream reach that was smaller than sand.

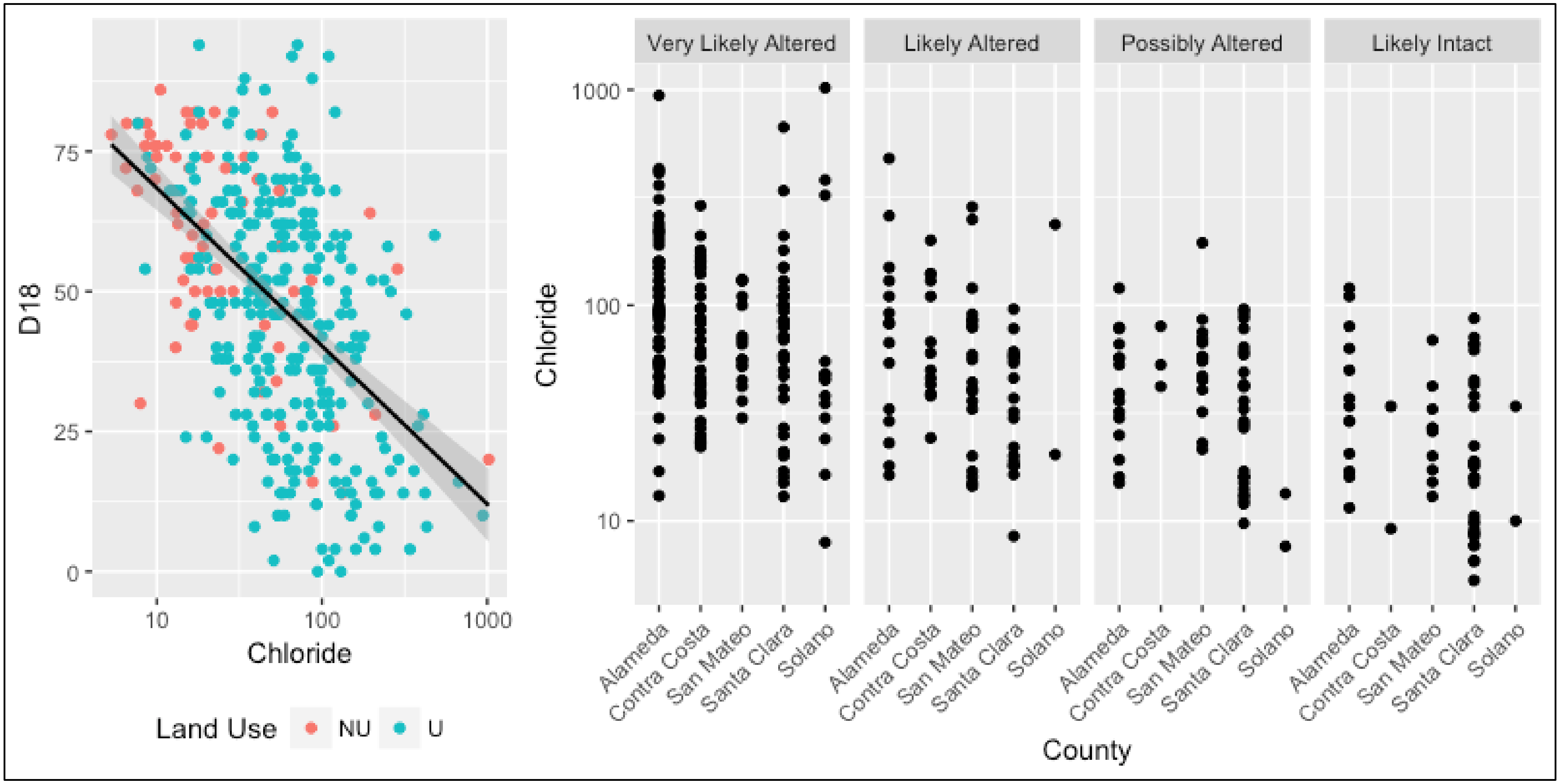

Figure 16. Relationship of D18 score to chloride concentration (mg/L). Note the chloride concentration scale is displayed in log units.

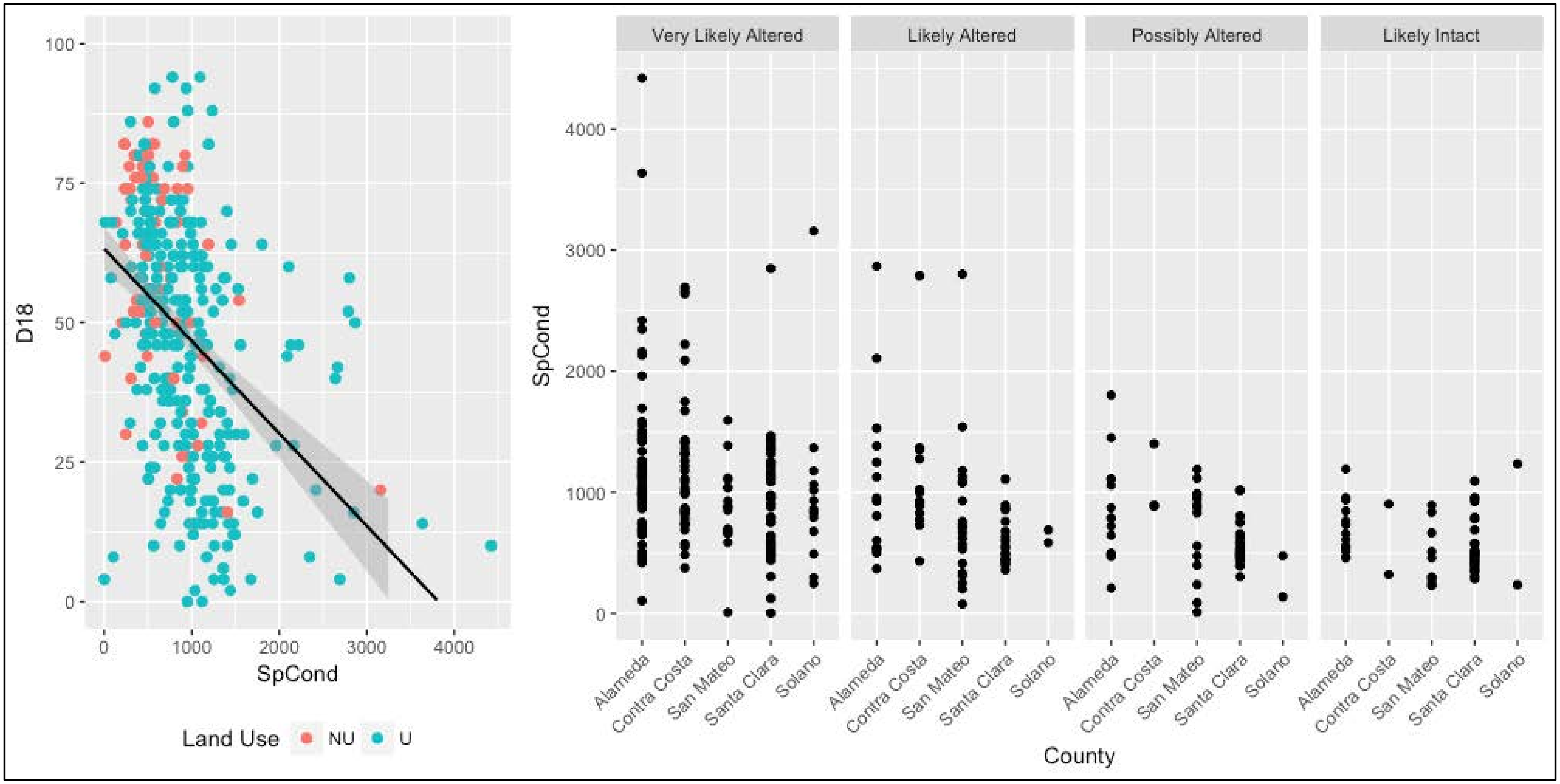

Figure 17. Relationship of D18 score to specific conductivity (µS/cm).

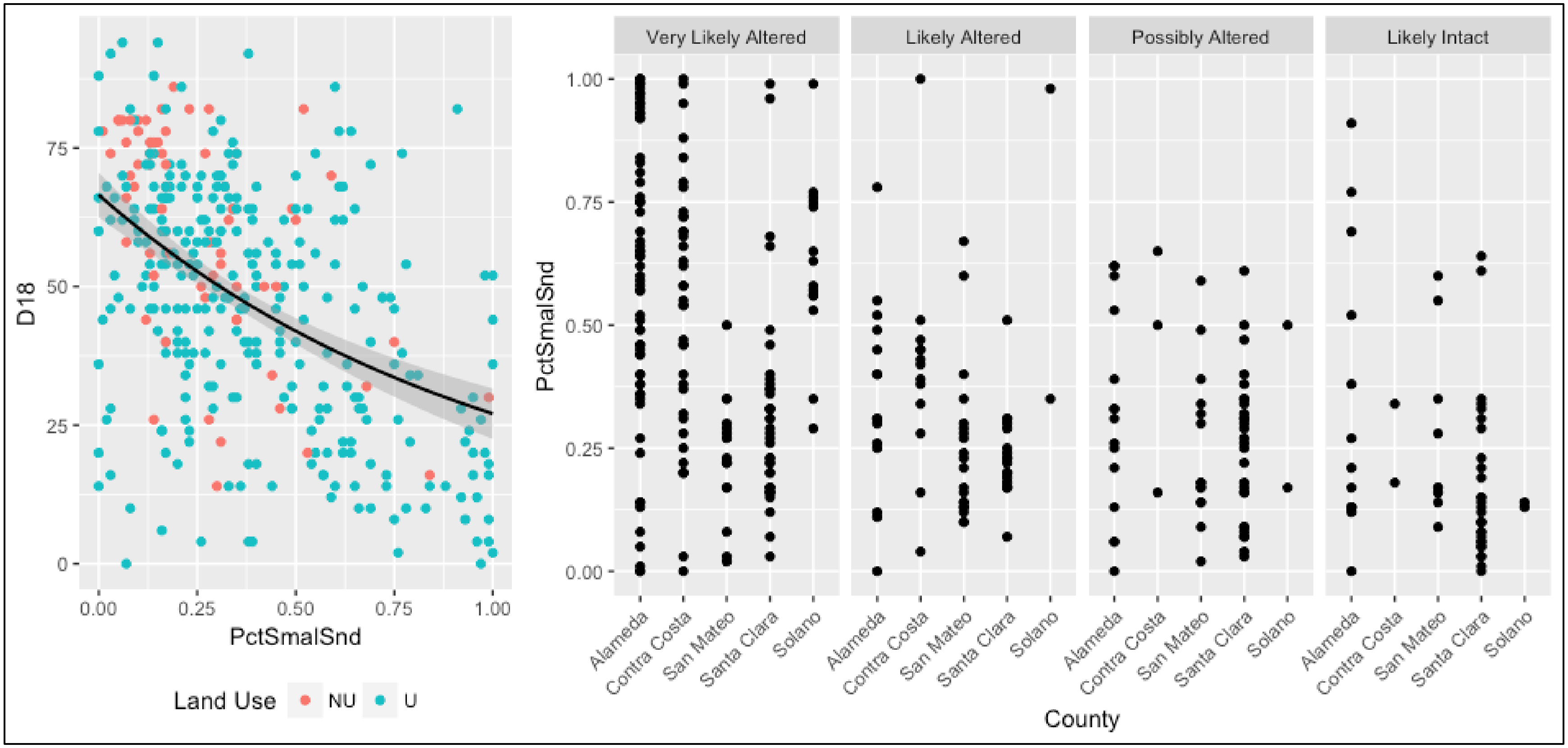

Figure 18. Relationship of D18 score to the percent of substrate in the stream reach that was smaller than sand.

3.3.2 Relative Risk Outputs

The relative risk of several stressors that may impact biological condition (based on CSCI scores) is shown in Figure 19. Definitions of abbreviations and threshold values for relative risk are described in Section 2.4.5. The Human Disturbance Index (HDI) stressor had the strongest relationship (> 3.0) with poor biological condition observed in the RMC dataset. Of the remaining physical habitat stressor variables, percent substrate smaller than sand (SmalSnd) had the strongest relationship (1.56) with poor biological condition. The remaining six stressors evaluated were associated with water quality and water chemistry and had Relative Risk values ranging between 1.26 and 1.51. These results are consistent with the random forest model results presented in the previous section, suggesting that physical habitat variables are more strongly associated with biological condition (based on CSCI scores) in the Bay Area, compared to water quality variables.

The relative risk for the eight stressors evaluated for RMC study were consistent with the results of the relative risk analysis of the same stressors that was conducted by the SMC (Mazor 2015a), with the exception of nutrients. The SMC study showed that relative risk for both Total Nitrogen and Phosphorus slightly under 3.0, while the RMC analysis indicated a much lower relative risk for each of these water quality parameters. The differences in relative risk of nutrients in Northern and Southern California suggest that there may be regional differences in the effects of these water quality parameters on biological condition (based on CSCI). However, it is important to note that the threshold values used by the SMC for Total Nitrogen and Phosphorus were lower than those used in the RMC data analyses.

Please note that the relative risk estimates for the eight stressors illustrated in Figure 19 could not be compared among RMC counties due to the insufficient number of sites with biological conditions above and below stressor thresholds in some counties.

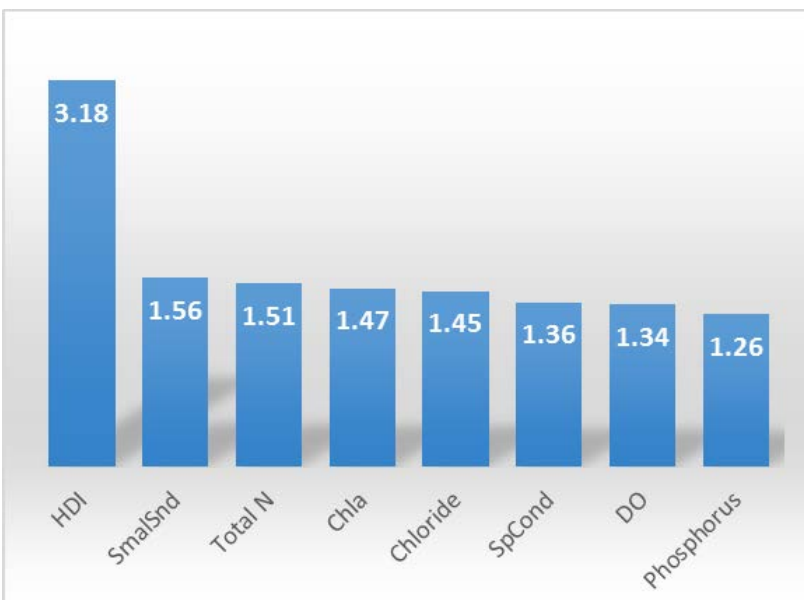

Figure 19. Relative risk of poor biological condition (i.e., scores in the lowest two CSCI condition categories) for sites that exceed stressor disturbance thresholds.

3.4 TRENDS

During the 2012-2016 monitoring period, there was no obvious temporal trend in biological condition, using either the CSCI, D18 or S2 indices. The median annual CSCI score for non-urban sites fluctuated between 0.518 and 0.931, but estimates in three of five years (2012, 2015, 2016) were only based on data collected at ten sites or less. Estimates were particularly imprecise for 2016, where only five non-urban sites were sampled. In urban areas, the median scores for CSCI had a much smaller range (0.408 to 0.510) than scores at non-urban sites. For urban sites, there was a clear lack of temporal trend, with 2016 exhibiting the highest median of the five years monitored (Figure 20).

D18 and S2 scores in each of the water years followed a similar pattern to CSCI scores. Scores in non-urban areas tended to vary widely depending on the water year and number of sites assessed (Figures 21 and 22). However, the urban sites tended to be relatively consistent, with scores generally being within a similar range each year. One observation to note was that S2 scores at urban sites were generally lower in 2016, compared to the preceding years of the survey, while CSCI scores were higher in 2016.

A comparison of median scores for CSCI each year and accumulated rainfall in each County did not reveal clear patterns on a county-by-county basis (Figure 23). Annual rainfall, as measured at San Francisco International Airport, during the five-year survey period was generally below the long-term average (Figure 5). Regional differences in accumulated rainfall additionally contribute to the lack of discernible changes in condition over time at a regional scale.

Contra Costa exhibited the highest range in accumulated rainfall during the monitoring period (10-20 inches) and generally had consistently low median CSCI scores. Alameda and Santa Clara counties, however, experienced a similar range in accumulated rainfall (5-16 inches), but had very different median CSCI scores in each water year. Given the variations in CSCI scores during different water years in some counties, future analyses to evaluate temporal trends in biological conditions will likely need to consider the influence of climatic variation at the county and regional-scales.

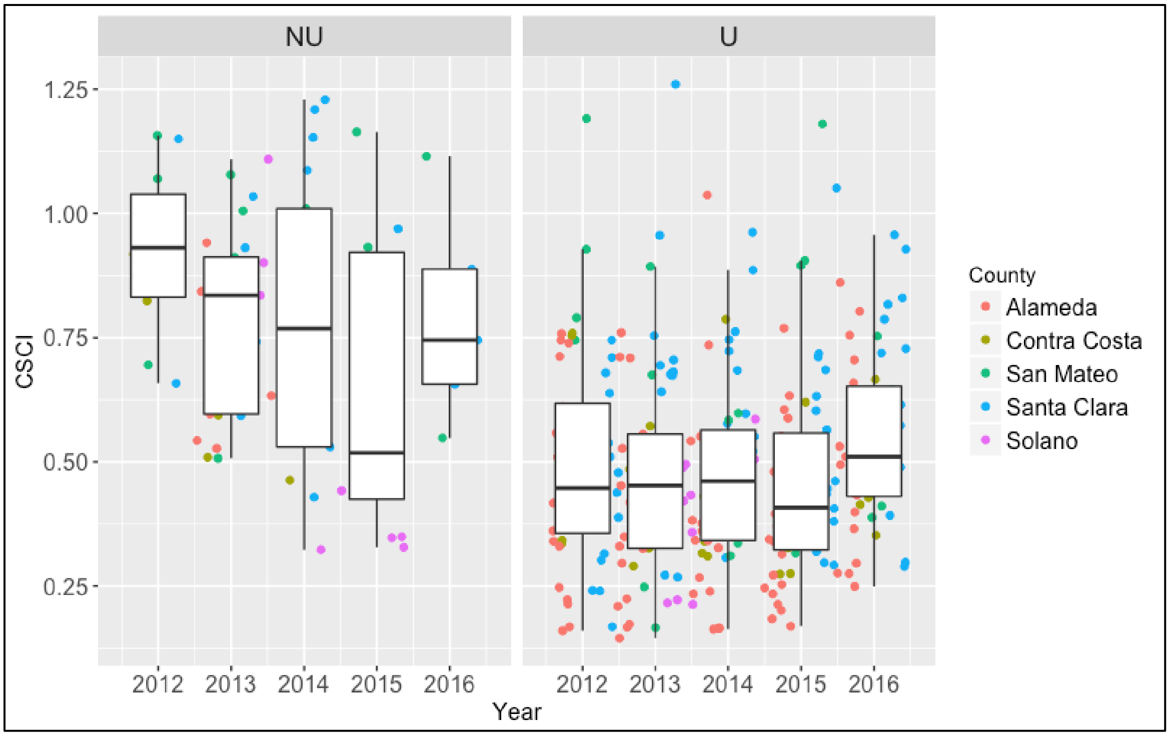

Figure 20. Distribution of CSCI scores during water years 2012-2016. NU = non-urban, U= urban.

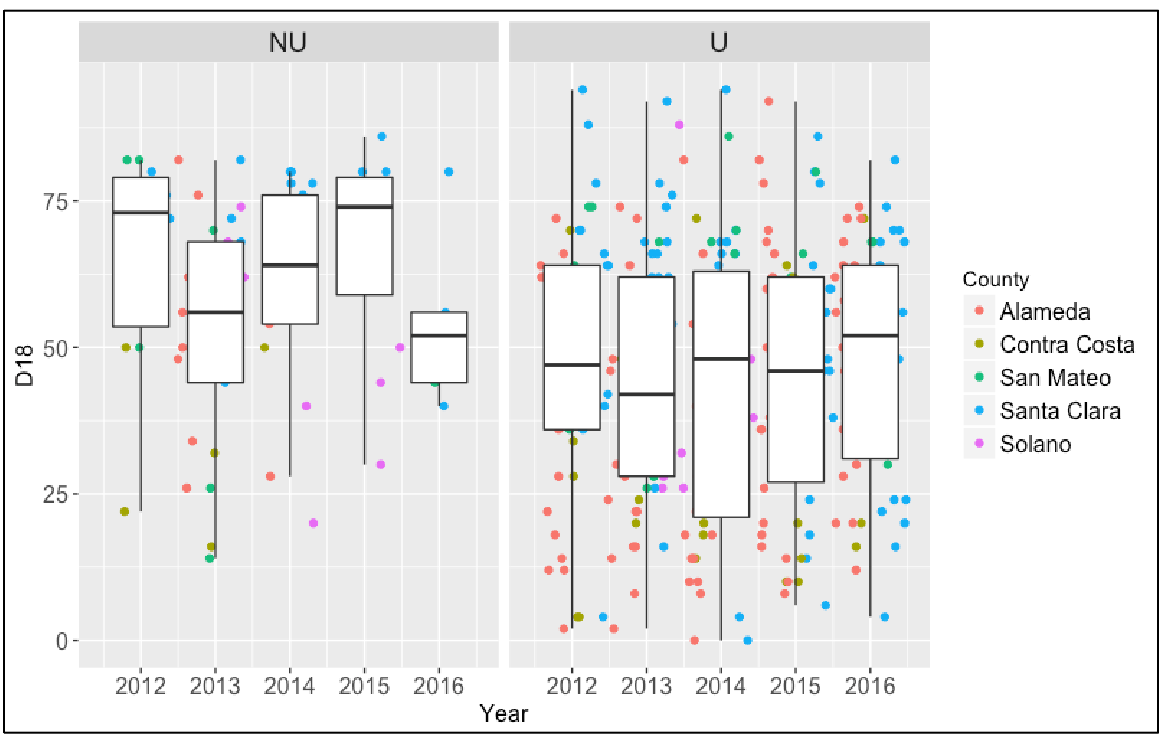

Figure 21. Distribution of D18 scores during water years 2012-2016. NU = non-urban, U= urban.

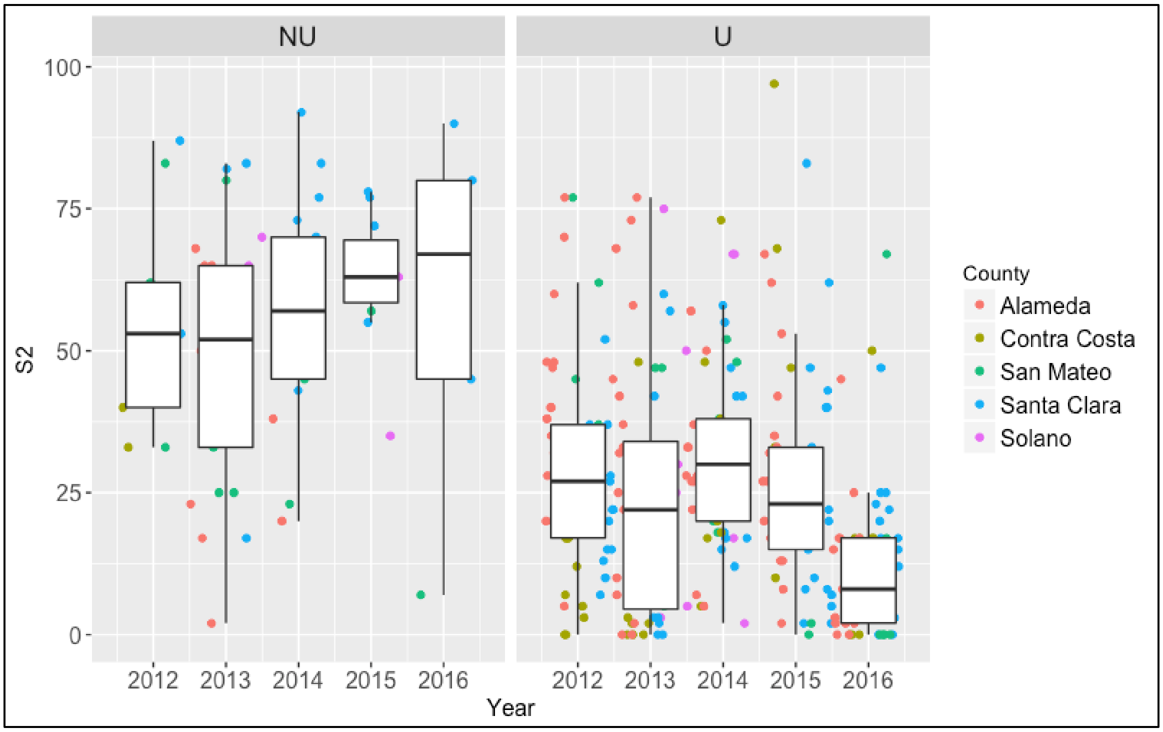

Figure 22. Distribution of S2 scores during water years 2012-2016. NU = non-urban, U= urban.

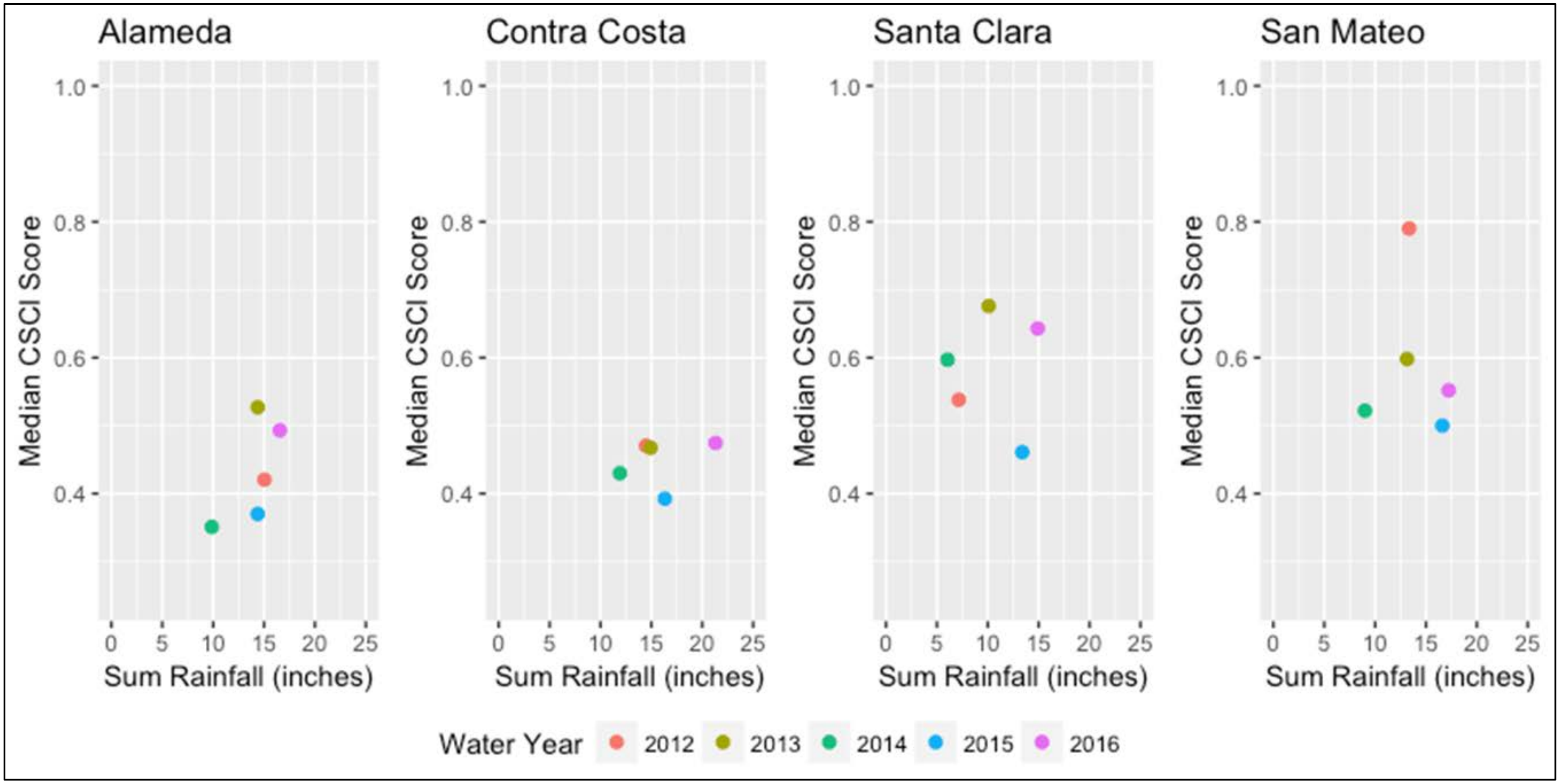

Figure 23. Relationship between median CSCI scores and accumulated annual rainfall in each County during water years 2012-2016. Includes urban and non-urban sites.

4 FINDINGS AND NEXT STEPS

The results and conclusions of the RMC's five-year bioassessment data evaluation are discussed below as they relate to the management questions and goals identified for the project.

4.1 *WHAT ARE THE BIOLOGICAL CONDITIONS OF STREAMS IN THE RMC AREA?*

Regional Conditions

The biological conditions of streams in the RMC area were assessed using two ecological indicators: BMIs and algae. The probabilistic survey design was developed to provide an objective estimate of biological condition of sampleable streams (i.e., accessible streams with suitable flow conditions) at both the RMC area and countywide scale.[7] Results of the survey indicate that streams in the RMC area are generally in poor biological condition:

- The CSCI for benthic macroinvertebrates (BMIs) indicates that 58% of stream length in the region are in the lowest CSCI condition category (Very Likely Altered); 74% of the of the sampled stream length exhibited CSCI scores below 0.795, the MRP trigger for potential follow-on activity.
- Using both algae indices (D18 and S2), stream conditions regionwide appear slightly less degraded than when using CSI, with approximately 40% of the streams ranked in the lowest algae condition category (Very Likely Altered). The algal indices also indicate that greater stream lengths (19-21%) are in the highest condition category (Likely Intact) compared to lengths in this category when the CSCI is used (15%).

These findings should be interpreted with the understanding that the survey focused on urban stream conditions. Approximately 80% of the samples (284 of 354) were collected at urban sites. As a result, the overall condition assessment represents the range of conditions found in the urban area, which is defined in the sample frame as areas classified as "urban" in the US Census (2000), plus all areas within city boundaries. Although the low non-urban sample size precludes making any definitive comparisons, bioassessment scores in the non-urban area were higher than scores in the urban area for each of the RMC counties. In general, the biological condition assessment for the RMC area (with a focus on urban sites) was consistent with the statewide assessment of biological conditions at sites located within urban land uses (PSA 2015), which resulted in more than 90% of urban streams rated in the two lowest biological condition categories using CSCI.

Differences Across Counties

One of the goals for the RMC monitoring design was to compare biological conditions of streams between counties. In general, biological conditions, based on CSCI and D18 scores, appeared better in streams located in Santa Clara and San Mateo counties, compared others. However, Santa Clara and San Mateo counties had proportionally more non-urban sites (with higher CSCI and D18 scores) compared to other

[7] More samples are needed to estimate condition for non-urban land use areas and finer spatial scales (i.e., watersheds).

counties. All counties exhibit higher biological condition scores in the non-urban area compared to the urban area. The difference between urban and non-urban median scores is lower for the D18 index, suggesting that diatoms may respond less to the habitat degradation commonly found at urban sites and may therefore provide better response to changes in water quality conditions.

Higher overall scores in Santa Clara and San Mateo may also be associated with regional differences in rainfall and flow duration. For example, San Mateo County and western Santa Clara County watersheds drain the Santa Cruz mountains, which typically receive higher rainfall, in contrast to Alameda and Contra Costa counties, which primarily contain watersheds that drain the western slopes of the drier Diablo range.

Indicator Tools

The use of multiple indicators provides a broad assessment of ecosystem functions. Streams that show degraded conditions for a single indicator may provide opportunities to identify the stressor and potentially implement management controls to reduce impacts. Alternatively, streams with poor conditions for both indicators (BMI and algae) may have multiple stressors that might be more challenging to address. Watershed managers may also choose to prioritize streams that are in good biological condition, based on both biological indicators, for protection of beneficial uses.

The RMC used existing tools to assess biological condition (CSCI and SoCal Algal IBIs). Although these tools were also used in the regional assessments conducted by the SMC, uncertainty remains as to how well these indices perform for streams within the San Francisco Bay Region:

- The CSCI is a statewide index that was developed for perennial streams. For the RMC project, however, the CSCI was used to evaluate BMI data collected in both perennial and non-perennial streams (note: the RMC assessed flow status by conducting site visits at all sampled sites during the dry season). In addition, CSCI scores appear highly sensitive to physical habitat degradation, which occurs frequently in the many highly modified urban streams monitored by the RMC. It is not clear how well the CSCI tool can show response to stressors associated with water quality, when physical habitat is the primary factor affecting the BMI community.

- For this report, the RMC evaluated algae data using SoCal Algae IBIs for diatoms (D18) and soft algae (S2). The D18 was more responsive to stressor gradients associated with water quality, however, high scores were often found in urban sites with highly degraded physical habitat. The soft algae index (S2) was not a reliable indicator of condition due to overall low taxa richness observed at both disturbed and undisturbed sites throughout the RMC area. In many cases, there was insufficient number of soft algae taxa to calculate S2, resulting in data gaps and lack of utility of the S2 index. Additional testing of soft algae indices is needed to assess the utility of this indicator in the RMC area.

  The State Water Board and Southern California Coastal Water Research Project are currently developing and testing a set of statewide indices using benthic algae data as a measure of biological condition for streams in California. The statewide Algae Stream Condition Indices (ASCIs) are expected to be finalized in 2019. It is anticipated that the RMC will apply the ASCIs to analyze algae data when they become available.

4.2 WHAT STRESSORS ARE ASSOCIATED WITH BIOLOGICAL CONDITIONS?

This question was addressed by evaluating the relationships between biological indicators (CSCI and D18) and stressor data through random forest and relative risk analyses. The study results indicate that each of the biological indicators responded to different types of stressors and therefore the two may be best used in combination to assess potential causes of poor (or good) biological conditions in streams:

- Biological condition, based on CSCI scores, is strongly influenced by physical habitat variables and land use within the vicinity of the site. The percent of the land area within a 5 km radius of a site that is impervious appears to have the largest influence on CSCI scores based on the random forest model results. Based on the relative risk analysis, the degree of human disturbance near a site, as observed via the Human Disturbance Index (HDI), appears to have the greatest relationship with poor biological condition of streams.
- Biological condition, based on D18 scores, is moderately correlated with water quality variables and less associated with physical or landscape variables, such as imperviousness or HDI.

In general, CSCI scores at urban sites were consistently low in all RMC counties, indicating that degraded physical habitat conditions in and around streams do not support healthy in-stream biological communities. D18 scores at urban sites were more variable, indicating that healthy diatom assemblages can occur at sites with poor physical habitat and may be important water quality indicator these sites.

No nutrient variables (e.g., nitrate, total nitrogen, orthophosphate, phosphorus) correlated strongly with CSCI scores in the Bay Area, nor were nutrients ranked as important variables explaining CSCI scores via the random forest model. Phosphorus and ash-free dry mass, which increase in response to biostimulation, were important in predicting algae (D18) index scores, although no statistically significant relationships were observed. This finding suggests that nutrient targets currently under development by the State Water Board as part of their Biostimulatory/Biointegrity Project, should be applied in the context of observed biological conditions, not uniformly based solely on broad relationships that may not apply to the Bay Area streams.

Although results show associations between some stressors and biological condition, they do not establish causation. There are several factors that may affect the strength of the correlation between stressors and biological condition:

- Stressors are not independent of one another and may have synergistic or mediating effects on condition. For example, elevated temperatures reduce the amount of oxygen that can be dissolved in the water column and both stressors may result in adverse effects to aquatic biota.
- Potential variability of stressor concentrations over time may not be represented in a single grab sample. For example, dissolved oxygen can have a wide range of concentrations over a 24-hour period. Drops in DO concentrations typically occur in early morning hours, potentially well prior to the timing of measurements during bioassessment events.
- Many of the physical habitat variables can be highly variable throughout the sample reach. For example, a wide range of substrate grain sizes can occur within a single transect. Thus, degraded habitat conditions that may exist at selected transect(s) of the assessment reach may not be well represented in reach-wide averages used as endpoints for the stressor analysis.

- Stressor impacts may be dependent on other factors (possibly not measured) for negative effects to occur. For example, elevated nutrient concentrations do not necessarily result in eutrophication (i.e., excessive plant and algal growth, reduced oxygen levels). Stream locations that have minimal exposure to sunlight, cooler water and higher flow rates may not develop eutrophic conditions, despite presence of elevated concentrations of nutrients.
- Stressors may have natural sources; prevalence and magnitude may vary by watershed or regionally. For example, naturally occurring nitrogen or phosphorus concentrations may be present in minimally disturbed upper watershed areas.

4.3 *Are Biological Conditions Changing Over Time?*

The short timeframe of the survey (five years) limited the ability to detect temporal trends in bioassessment data. Since new sites are surveyed each year, it is expected that a much longer time period is needed to detect trends at a regional scale over time. The variability in biological condition observed over the five years of the current analysis may have been associated with annual variation in precipitation or other factors. Drought conditions were present during the first four years of the survey. Trends in biological condition are more likely to occur on the decadal timescale. That said, the PSA evaluated trends for unique probabilistic sites sampled over a 13-year period and observed no trends (i.e., consistent directional change over time) (PSA 2015).

It is also important to consider these results within the broader context of the progress made over the past decade to reduce the effects of urbanization on creeks and channels through the mandatory treatment of stormwater and reduction of impervious areas via applicable new and redevelopment projects, and the numerous stream restoration projects that have been put into place. The implementation of mandatory stormwater treatment via green stormwater infrastructure (GSI) and low impact development (LID) began prior to the adoption of the MRP in 2005. These requirements reduce the effects of stormwater from impervious surfaces created via new and redevelopment and likely have positive effects on biological condition in streams, although the responses may be delayed. Bay Area municipalities are currently developing GSI Plans, which will result in the strategic and widespread integration of GSI into Capital Improvement Projects and other co-benefit projects like regional stormwater capture projects, creek restoration and flood control and resiliency projects. These efforts are anticipated to further reduce the impacts of stormwater on local streams. Future creek status monitoring may provide additional insight into the potential positive impacts of GSI and creek restoration on water quality and beneficial uses in urban creeks.

The ability to detect trends would be increased if the sample design included re-visiting sites over multiple years. Multiple surveys at individual sites would provide more site-specific detection of changing biological conditions over time. Should RMC participants intend to use BMIs and algae as long-term indicators, analyses should be conducted to identify the minimum number of samples needed over a specified timeframe to detect trends at a site or within a watershed or county, with a specified level of confidence. The analysis could also be used to optimize the monitoring program by evaluating appropriate sample sizes for detecting trends when considering expected variability in condition for different groups of sites, land use types, or areas where management actions are being implemented.

4.4 EVALUATION OF MONITORING DESIGN

The information presented below is intended to provide recommendations on potential revisions RMC monitoring procedures that should be considered for future implementation of bioassessment programs in the Bay Area.

4.4.1 Site Evaluations

Over the first five years of monitoring, the RMC evaluated about 25% (1455 out of 5740) of the sites in the sample frame to assess 354 sites. Approximately 46% (873 out of 1896) of the total number of urban sites in the sample frame were evaluated during that time. Additional sites have subsequently been selected from the sample frame and evaluated for sampling in 2017 and 2018. The number of remaining sites for evaluation in the RMC Sample Frame for each county is presented in Table 7.

Table 7. Sites remaining in RMC sample frame before site evaluation in water year 2019.

<table>
<tr><th>County</th><th>Urban</th><th>Non-urban</th></tr>
<tr><td>Alameda</td><td>124</td><td>797</td></tr>
<tr><td>Contra Costa (R2)</td><td rowspan="2">348</td><td>307</td></tr>
<tr><td>Contra Costa (R5)</td><td>331</td></tr>
<tr><td>Santa Clara</td><td>143</td><td>1189</td></tr>
<tr><td>San Mateo</td><td>67</td><td>469</td></tr>
<tr><td>Fairfield-Suisun</td><td>37</td><td rowspan="2">208</td></tr>
<tr><td>Vallejo</td><td>4</td></tr>
</table>

Based on rejection rates from previous years, the sample frame is anticipated to only last two to three years at which time the urban sites in the frame will be exhausted. Revision of the RMC monitoring design could seek to reduce the future rejection rate through re-evaluation of the sample frame to exclude areas of low management interest or regions that would not be candidates for sampling (such as due to lack of permissions or physical barriers to access). This would improve the spatial balance of samples that more closely represents the proportion of the sample frame that can be reliably assessed.

Each countywide stormwater program managed their site evaluation information independently using a standardized database. The site evaluation data were then compiled to conduct the spatial analysis needed to calculate the regional biological condition estimates presented in this report. During the compilation process, inconsistencies in procedures used to conduct site evaluation (BASMAA 2016a) were identified that affect the statistical certainty of the regional estimates. Some sites in the sample draw were skipped over (e.g., challenges in obtaining permissions from private land owners, lack of flow during period of drought) with the intention to re-evaluate the sites at a future date. The skipped sites created sampling bias that affects the spatial balance of the draw and reduces certainty in the condition estimates.

Another issue was the disproportionate sampling of non-urban sites among the counties. The RMC intended to sample twenty percent of the targeted sites each year. Some Programs had difficulty getting access to non-urban sites, or decided to focus on urban sites, resulting in a wide range in number of samples collected at non-urban sites across the counties. As a result, biological condition scores at the county-scale tended to be higher in counties that sampled more non-urban sites.

4.4.2 RMC Sample Frame

Consistent with the PSA, the RMC sample design was created to probabilistically sample all streams within the RMC area, which resulted in a master list of 33% urban sites and 67% non-urban sites. However, because participating municipalities are primarily concerned with runoff from urban areas, the RMC focused sampling efforts on urban sites (80%) over non-urban sites (20%). As a result, non-urban samples are under-represented in the dataset resulting in much lower overall biological condition scores than would be expected for a spatially balanced dataset. In addition, the limited number of non-urban samples (2% sample frame assessed thru-2016) prevented statistical confidence in estimates of biological condition for non-urban land use at the regional scale.

Depending on the goals for the RMC moving forward, the RMC may want to consider developing a new sample draw that establishes a new list of sites that is weighted for specific land uses categories and Program areas of interest. Development of a revised sample frame would result in a new list of sites, associated with different length weights for each land use category. The sample draw could also include a list of sites for oversampling (replacements for sites not sampled) to maintain the spatial balance throughout any timeframe of the draw and allow for a much longer time frame before the list is exhausted.

Re-design of the RMC sample frame could also include new strata based on developed channel classifications created by SCCWRP. The classifications are created using a statistical model that predicts likely ranges of CSCI scores based on landscape characteristics (Mazor et al. 2018). These channel classifications could be integrated as strata into the RMC sample frame to allow varying sampling efforts for urbanized streams.

4.5 Possible Next Steps for the RMC Bioassessment Monitoring

Based on evaluation of data collected during the five years of the survey, several options to revise the RMC Monitoring Design are presented below:

1) Continue to sample new probabilistic sites until the draw is exhausted;
2) Re-visit probabilistic sites in support of assessing temporal trends;
3) Monitor targeted sites for special studies; or
4) Combination of two or more of the above.

Each of these options is discussed in more detail below.

<u>Continue Sampling New Probabilistic Sites</u>

The RMC could continue to sample new probabilistic sites from the current sample frame with the goal to establish baseline conditions over smaller spatial scales. Eventually, statistically significant datasets would be obtained to estimate biological condition for all strata previously considered (i.e., non-urban and countywide), as well as finer scales (e.g., watersheds). Smaller geographic scales of assessments may provide stronger associations between biological conditions and stressor levels. Watershed-level assessments may provide managers more opportunities to evaluate spatial patterns and temporal trends for specific watersheds.

Exclusively sampling new sites would exhaust sites in the current sample draw. It is anticipated that at the current rate of sampling (at same proportion of urban/non-urban sites), some of the Programs would run out of urban sites in two to three years. Solano County has already depleted urban sites from their sample frame. Sampling effort at new non-urban sites should be also be evaluated. Resources to conduct site evaluations (e.g., permission to access private property) are typically much higher at non-urban sites. In addition, the access to non-urban sites appears to be highly variable by county.

If this option is desired, the RMC could develop a new probabilistic sample draw with a list of oversample sites.

Re-visit Probabilistic Sites to Assess Temporal Trends

Re-visiting probabilistic sites previously sampled may provide trend estimates and more refined information to potentially explain causes of observed trends. The most robust trends scenario would involve sampling the same sites each year; however, given the current level-of-effort, this would only be possible at a relatively small number of sites in each county. Thus, the resulting trends assessment could only answer regional questions. Some sites could be sampled for multiple years to evaluate potential variability related to changes in precipitation; non-urban sites may be particularly sensitive to annual variation in precipitation. Integrating site re-visits into the sample design would have the advantage of extending the life of the sample frame (i.e., reduce number of new sites each year).

Targeted Studies

There are several potential objectives for conducting biological assessments at targeted sites, including:

1) Evaluate effectiveness of stream restoration/BMP implementation projects;
2) Determine source/stressor at impaired site (i.e., causal assessment);
3) Evaluate conditions in selected watersheds;
4) Study trends at minimally disturbed sites (e.g., climate change);
5) Assess validity of CSCI in nonperennial streams in the Bay Area;
6) Investigate variability in biological indicator scores within sampling index period.

Targeted studies could be coordinated among RMC participants to evaluate similar objectives at regional scale or could be done independently by each Program. It is anticipated that targeted studies may require more resources with regards to site selection, data needs, detailed analyses, and reporting. However, targeted monitoring could also leverage requirements that Permittees have for other projects.

Combined Approaches

The RMC may consider implementing a combination of all the approaches described above for the future monitoring design.

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APPENDICES

APPENDIX 1 RANDOM FOREST ANALYSIS

Table 1-A. Variable group, variable code, and description of response variables (condition indices) and explanatory environmental variables (landscape, habitat, and water quality) used for random forest model development.

Variable Group	Variable Code	Description
Response	CSCI	California Stream Condition Index
Response	D18	Soft algae condition score
Habitat	AvAlgCov	Mean Filamentous Algae Cover
Habitat	AvBold	Mean Boulders cover
Habitat	AvWetWd	Mean Wetted Width/Depth Ratio
Habitat	AvWoodD	Mean Woody Debris <0.3m cover
Habitat	ChanAlt	Channel Alteration Score
Habitat	EpiSub	Epifaunal Substrate Score
Habitat	FlowHab	Evenness of Flow Habitat Types
Habitat	NatShelt	Natural Shelter cover - SWAMP
Habitat	NatSub	Evenness of Natural Substrate Types
Habitat	PctBold_L	Percent Boulders - large
Habitat	PctBold_LS	Percent Boulders - large & small
Habitat	PctBold_S	Percent Boulders - small
Habitat	PctFin	Percent Fines
Habitat	PctFstH20	Percent Fast Water of Reach
Habitat	PctGra	Percent Gravel - coarse
Habitat	PctSlwH20	Percent Slow Water of Reach
Habitat	PctSmalSnd	Percent Substrate Smaller than Sand (<2 mm)
Habitat	PctSnd	Percent Sand
Habitat	ShD.AqHab	Shannon Diversity (H) of Aquatic Habitat Types
Habitat	ShD.NatSub	Shannon Diversity (H) of Natural Substrate Types

Variable Group	Variable Code	Description
Land Use	HDI	Combined Riparian Human Disturbance Index - SWAMP
Land use	PctImp	Percent Impervious Area of Reach
Land use	PctImp_1K	Percent Impervious Area in 1km
Land use	PctImp_5K	Percent Impervious Area in 5km
Land use	PctUrb	Percent Urban Area of Reach
Land use	PctUrb_1K	Percent Urban Area in 1km
Land use	PctUrb_5K	Percent Urban Area in 5km
Land use	RdCrs_5K	Number Road Crossings in 5km
Land use	RdCrs_W	Number Road Crossings in watershed
Land use	RdDen_1K	Road Density in 1km
Land use	RdDen_5K	Road Density in 5km
Land use	RdDen_W	Road Density in watershed
Land use	RoadCrs_1K	Number Road Crossings in 1km
Water Quality	AFDM.sub	Ash Free Dry Mass
Water Quality	Ammonia.sub	Ammonia
Water Quality	Chla.sub	Chlorophyll a
Water Quality	Chloride	Chloride
Water Quality	DO	Dissolved oxygen
Water Quality	Nitrate.sub	Nitrate
Water Quality	Nitrite.sub	Nitrite
Water Quality	OP.sub	Orthophosphate
Water Quality	pH	pH
Water Quality	Phosphorus.sub	Phosphorus
Water Quality	Silica	Silica
Water Quality	SpCond	Specific conductivity
Water Quality	Temp	Temperature
Water Quality	TKN.sub	Total Kjeldahl Nitrogen

Variable Group	Variable Code	Description
Water Quality	Total N	Total Nitrogen
Water Quality	UIA.sub	Unionized Ammonia

Table 1-B. Model and cross-validation statistics for random forest models with CSCI and D18 scores using the final set of model variables (Table 2, Table 3)

Index	Model Dataset	Model Statistic	
CSCI	Training	R^2	0.95
	Validation	R^2	0.61
CSCI	Training	CV R^2	0.66
	Validation	CV R^2	0.52
D18	Training	R^2	0.92
	Validation	R^2	0.34
D18	Training	CV R^2	0.35
	Validation	CV R^2	0.33

Training and validation models run with the same variables, *R^2 = adjusted R-squared, CV R^2 = Cross validation R^2

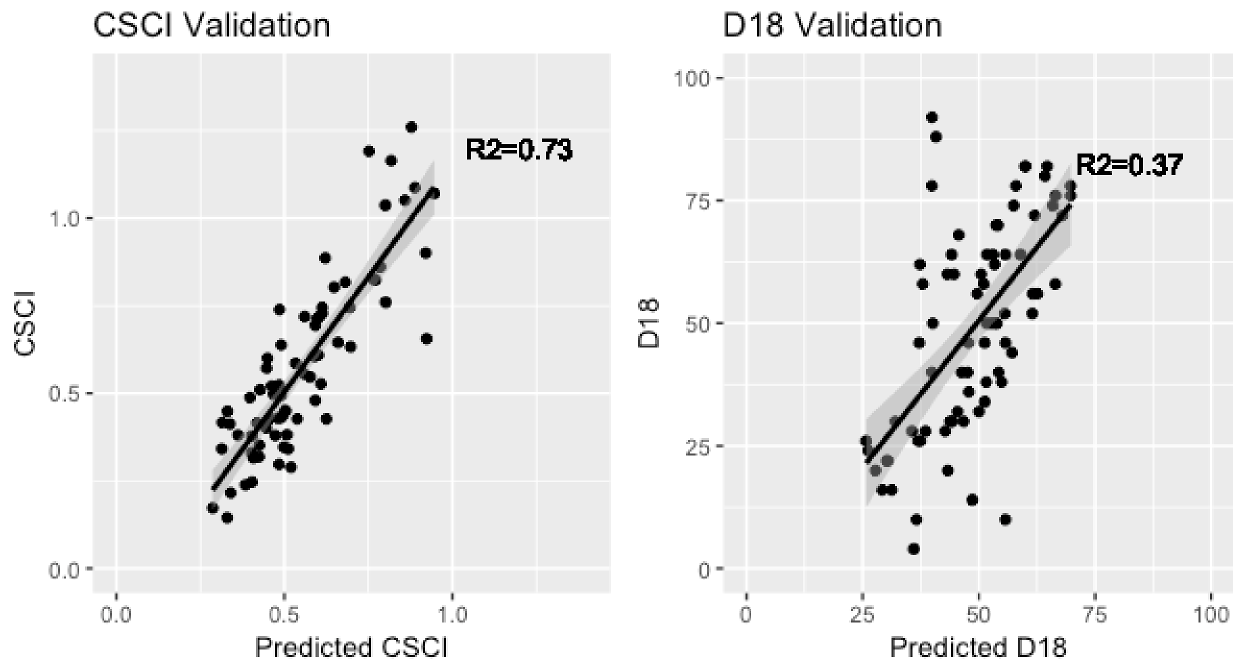

Figure 1-A. Relationship of observed to predicted CSCI and D18 scores in the validation dataset using all 49 explanatory variables in Step 1 of the random forest trial

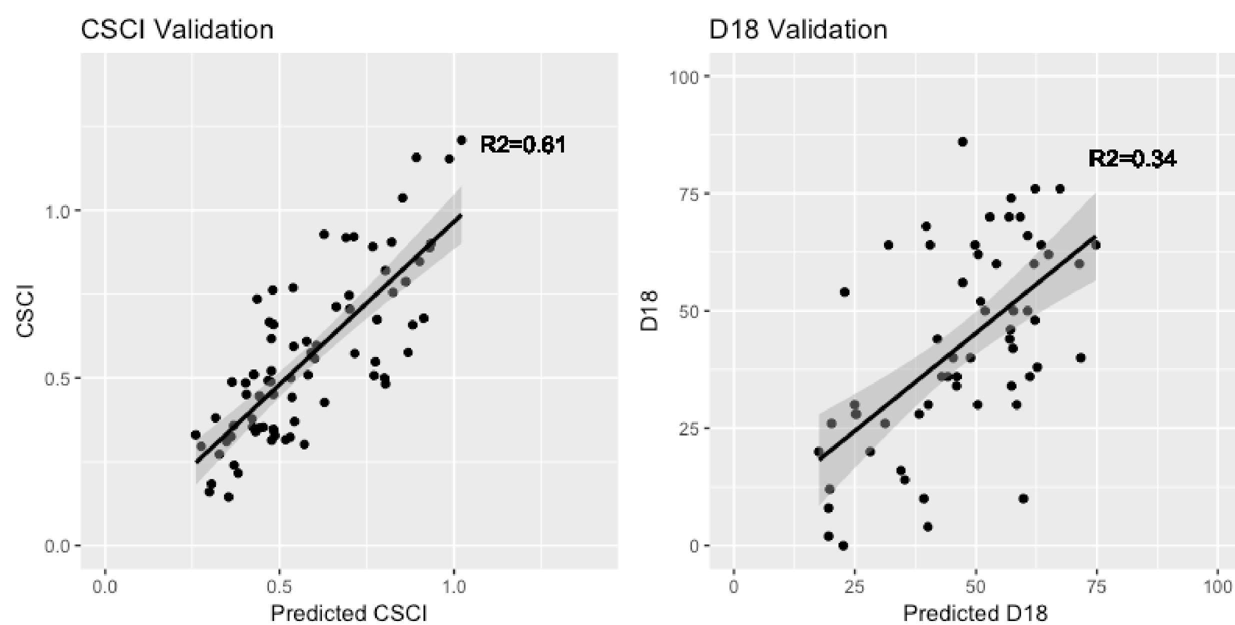

Figure 1-B. Relationship of observed to predicted CSCI and D18 scores in the validation dataset using the final, selected list of explanatory variables in Step 2 of the random forest trial

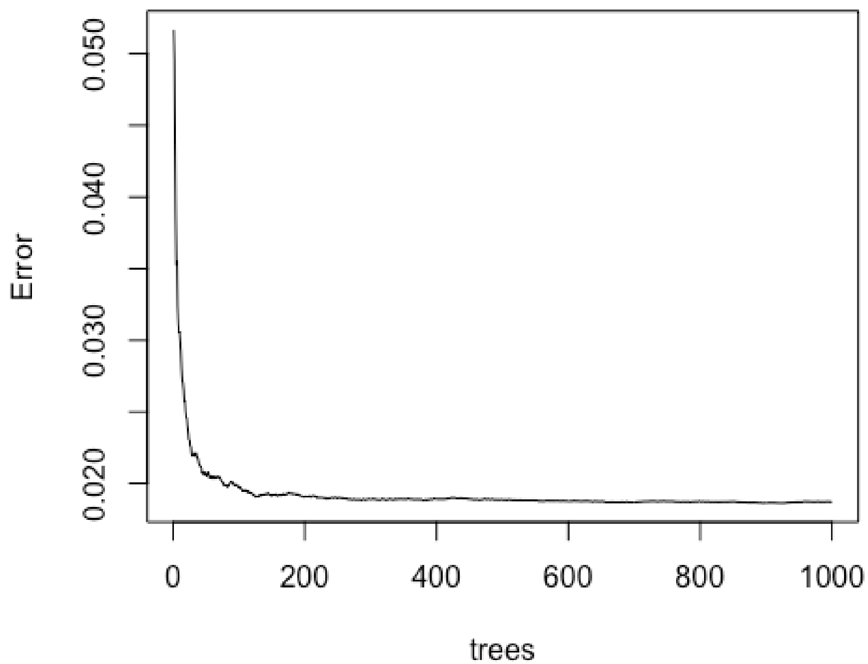

Figure 1-C. Prediction error vs. number of trees in the CSCI model with 49 stressor variables

APPENDIX 2 PARTIAL DEPENDENCY PLOTS

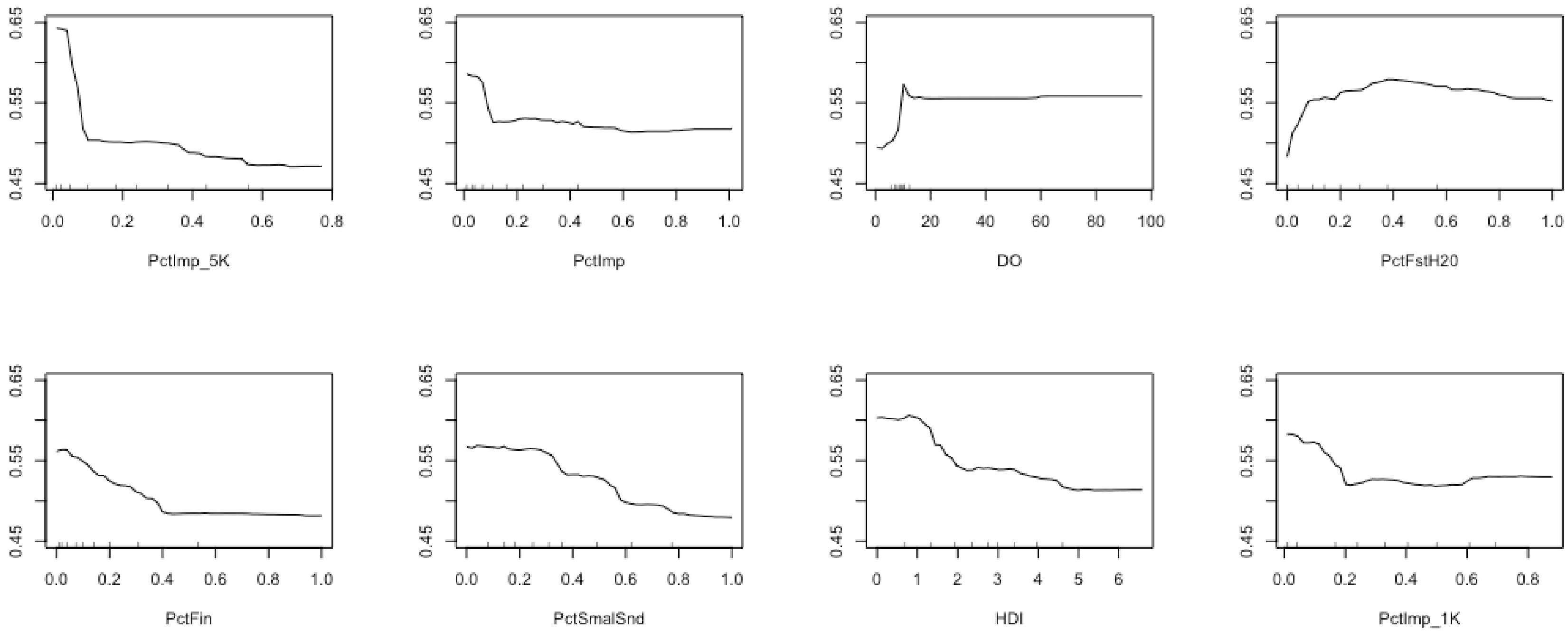

Figure 2-A. Partial dependency plots for stressor variables in random forest model of CSCI condition. Plots show the predicted response of CSCI (y-axis) based on the effect of individual explanatory variables (x-axis) with the response of all other variables removed in the training data set.

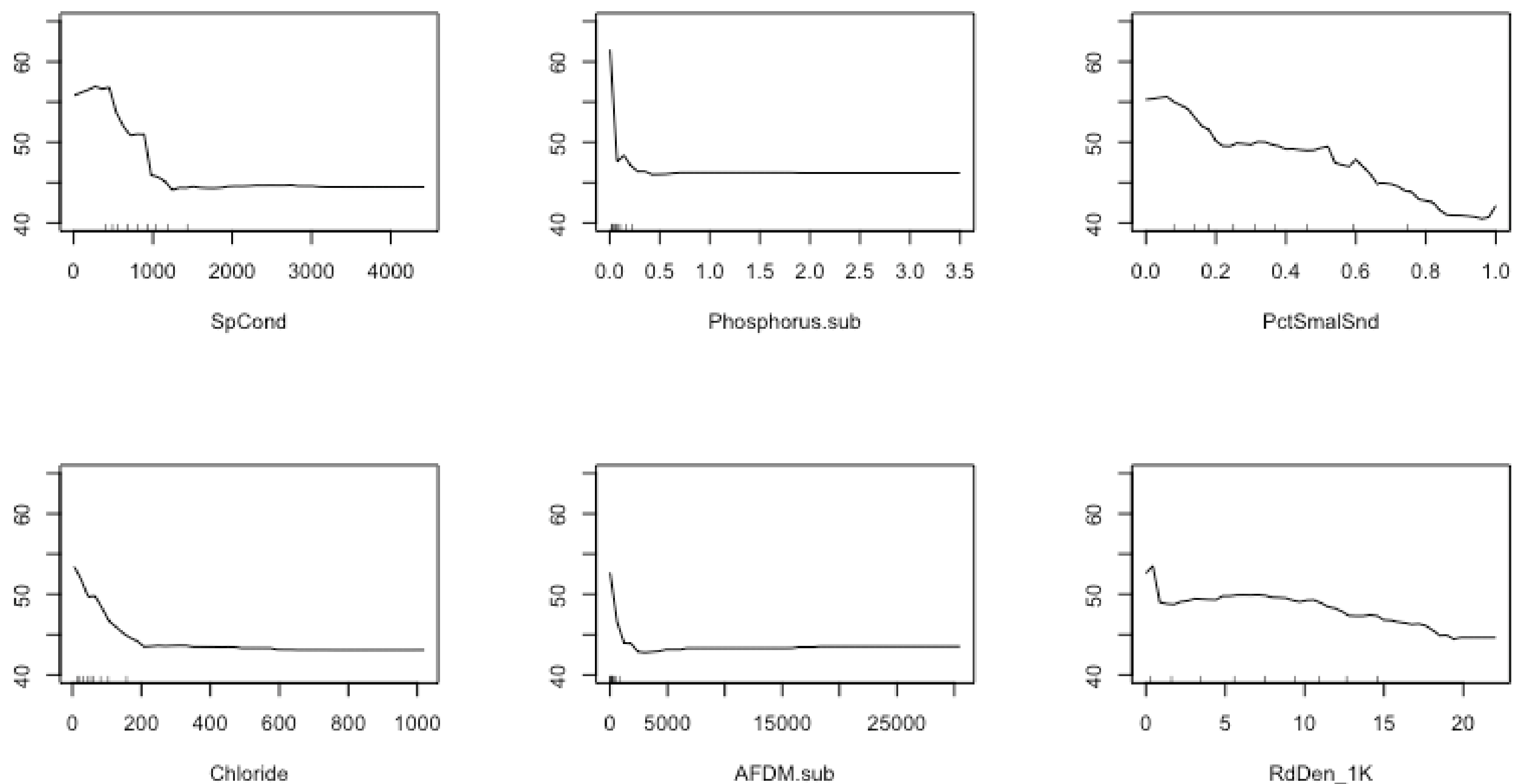

Figure 2-B. Partial dependency plots for stressor variables in random forest model of D18 condition. Plots show the predicted response of D18 (y-axis) based on the effect of individual explanatory variables (x-axis) with the response of all other variables removed in the training data set.

APPENDIX 3 CSCI-STRESSOR PLOTS

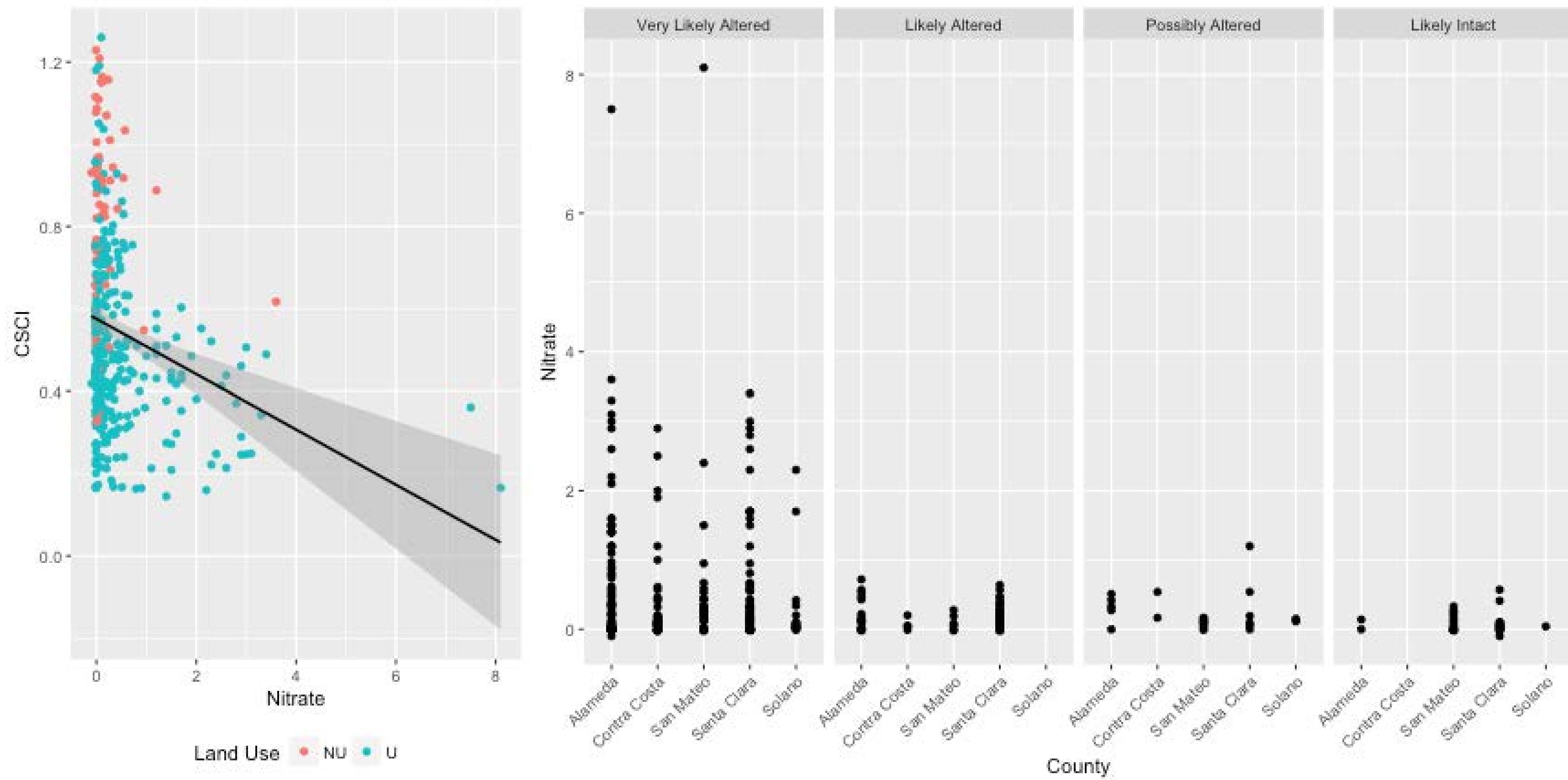

Figure 3-A. Relationship of Nitrate concentration to CSCI scores

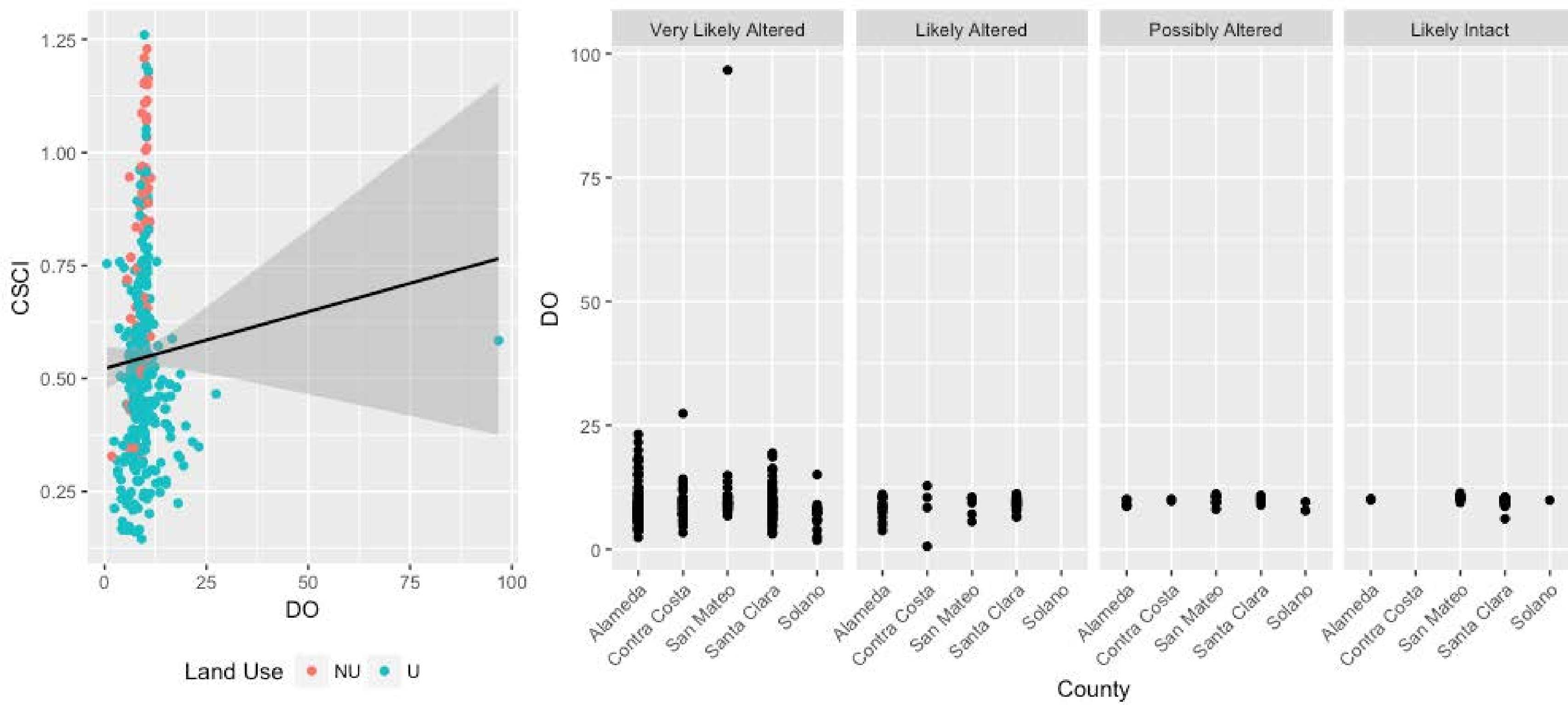

Figure 3-B. Relationship of Dissolved Oxygen values to CSCI scores

APPENDIX 4 ADDITIONAL FIGURES

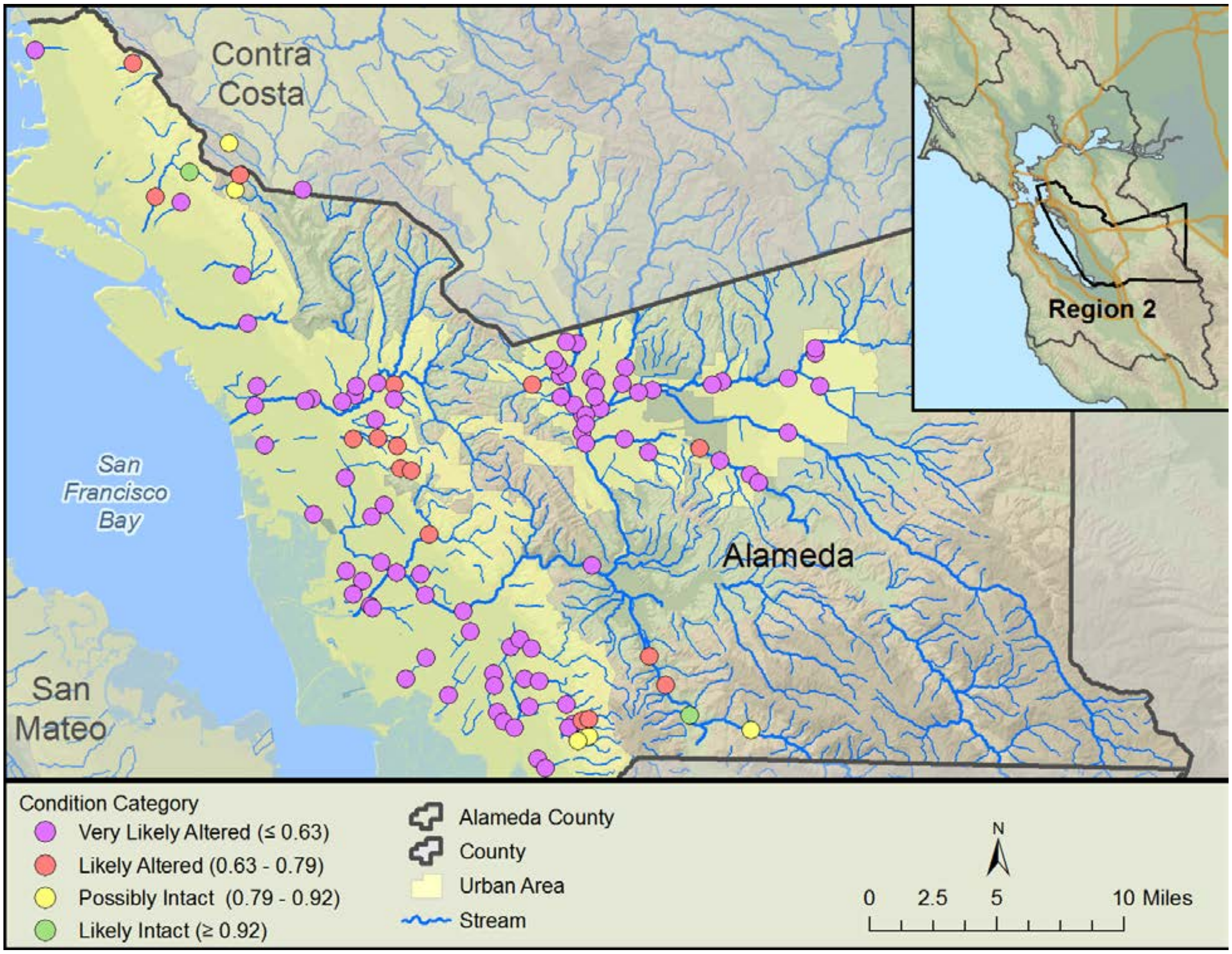

Figure 4-A. Biological condition based on CSCI scores in Alameda County.

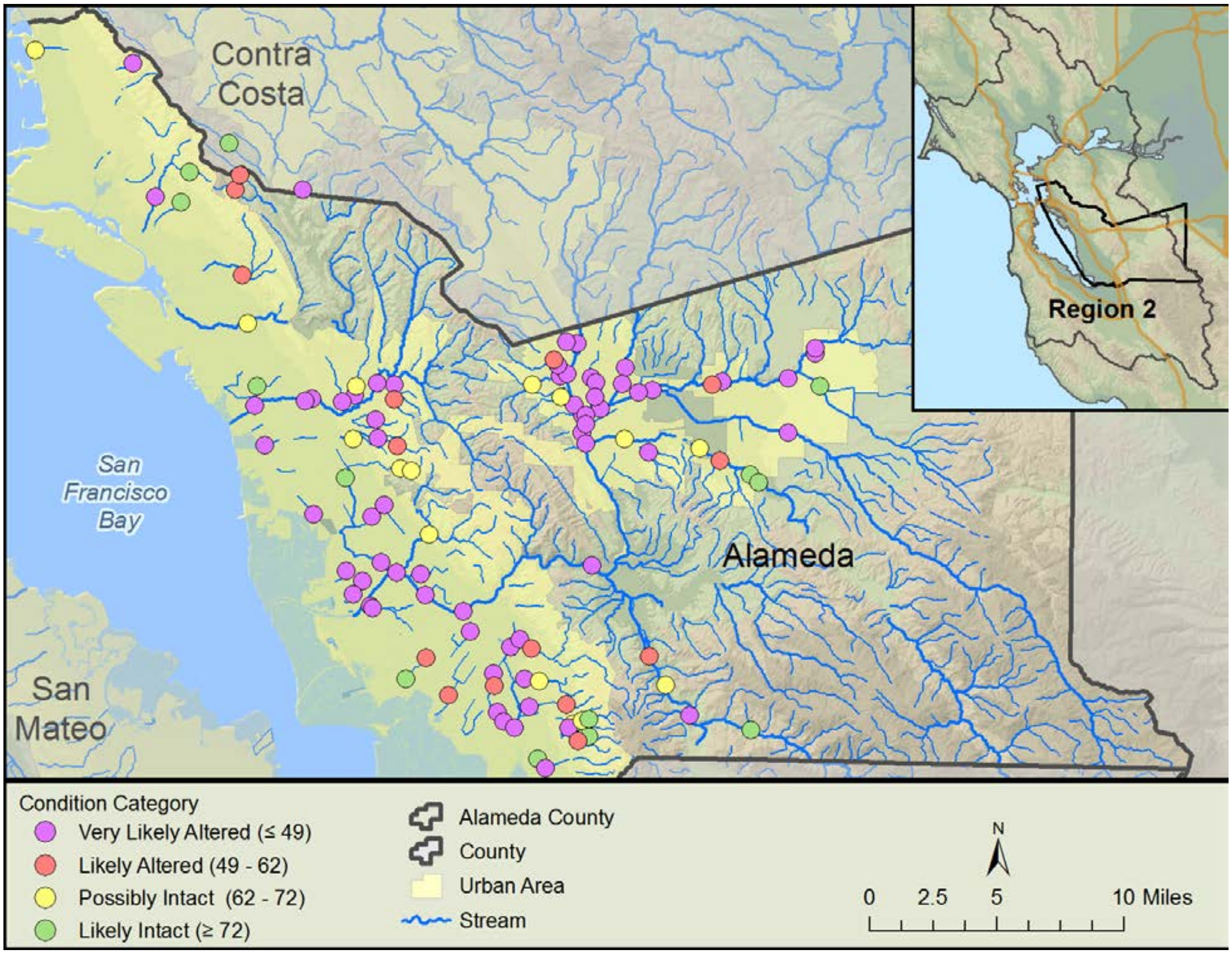

Figure4-B. Biological condition based on D18 scores in Alameda County.

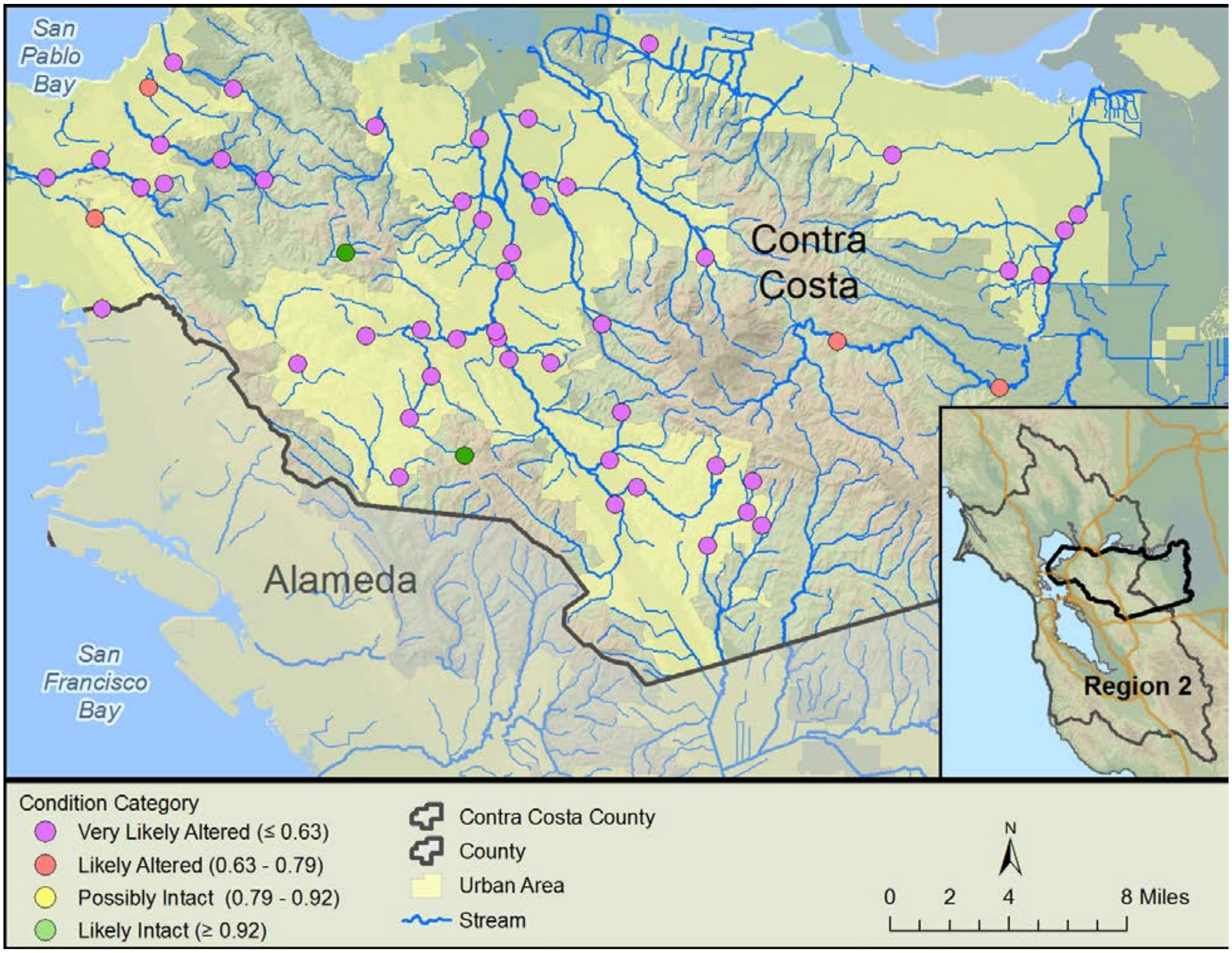

Figure 4-C. Biological condition based on CSCI scores in Contra Costa County.

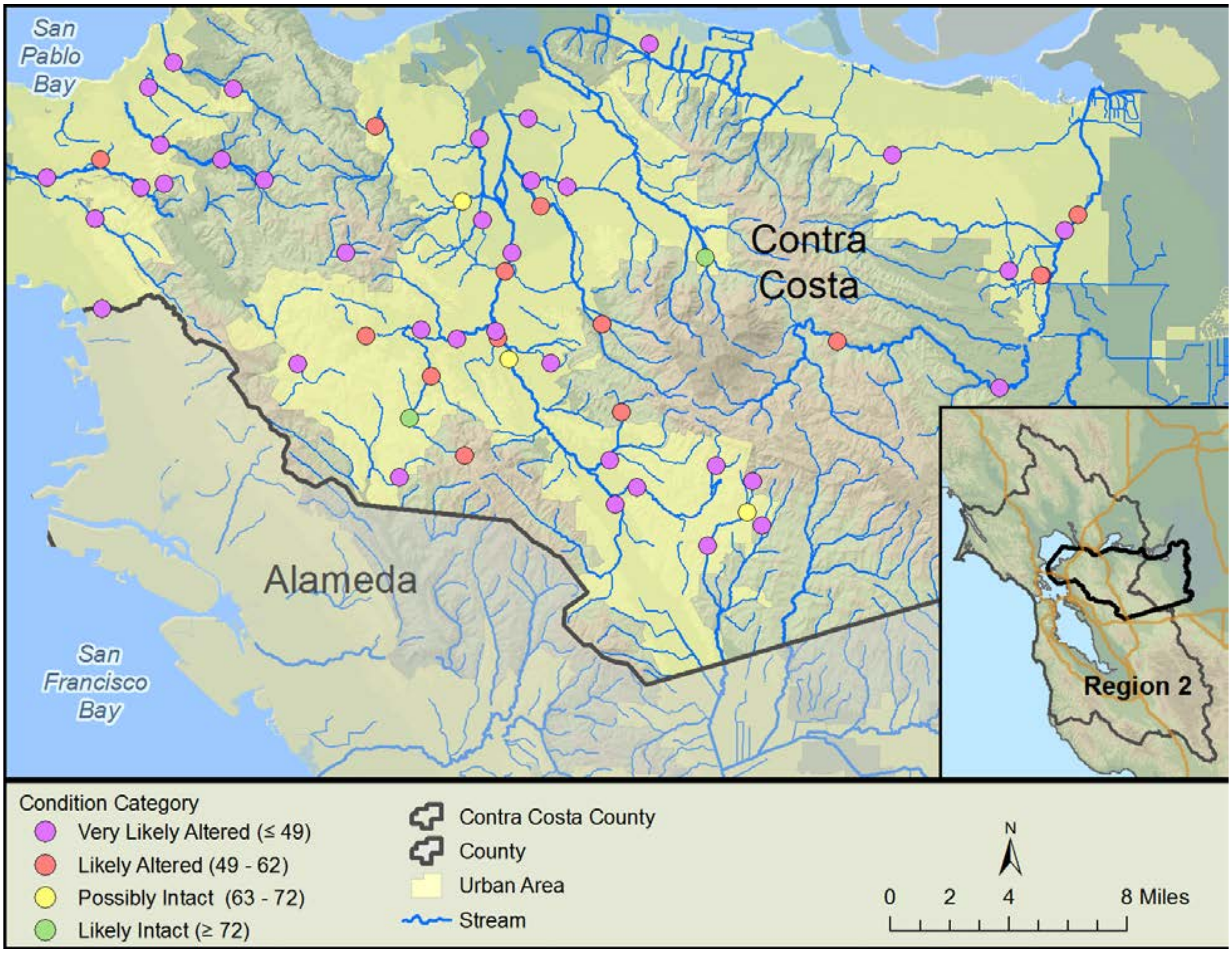

Figure 4-D. Biological condition based on D18 scores in Contra Costa County.

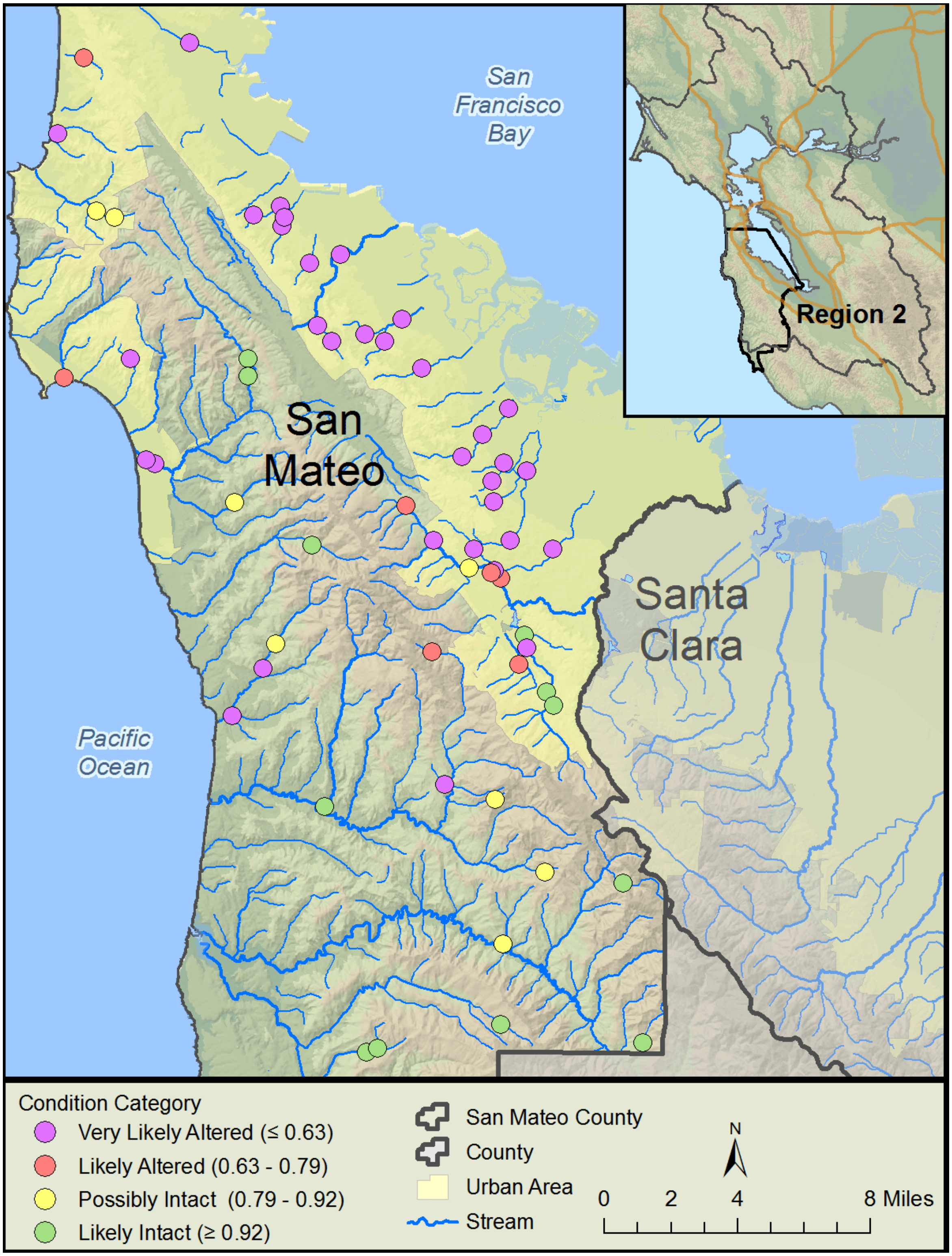

Figure 4-E. Biological condition based on CSCI scores in San Mateo County.

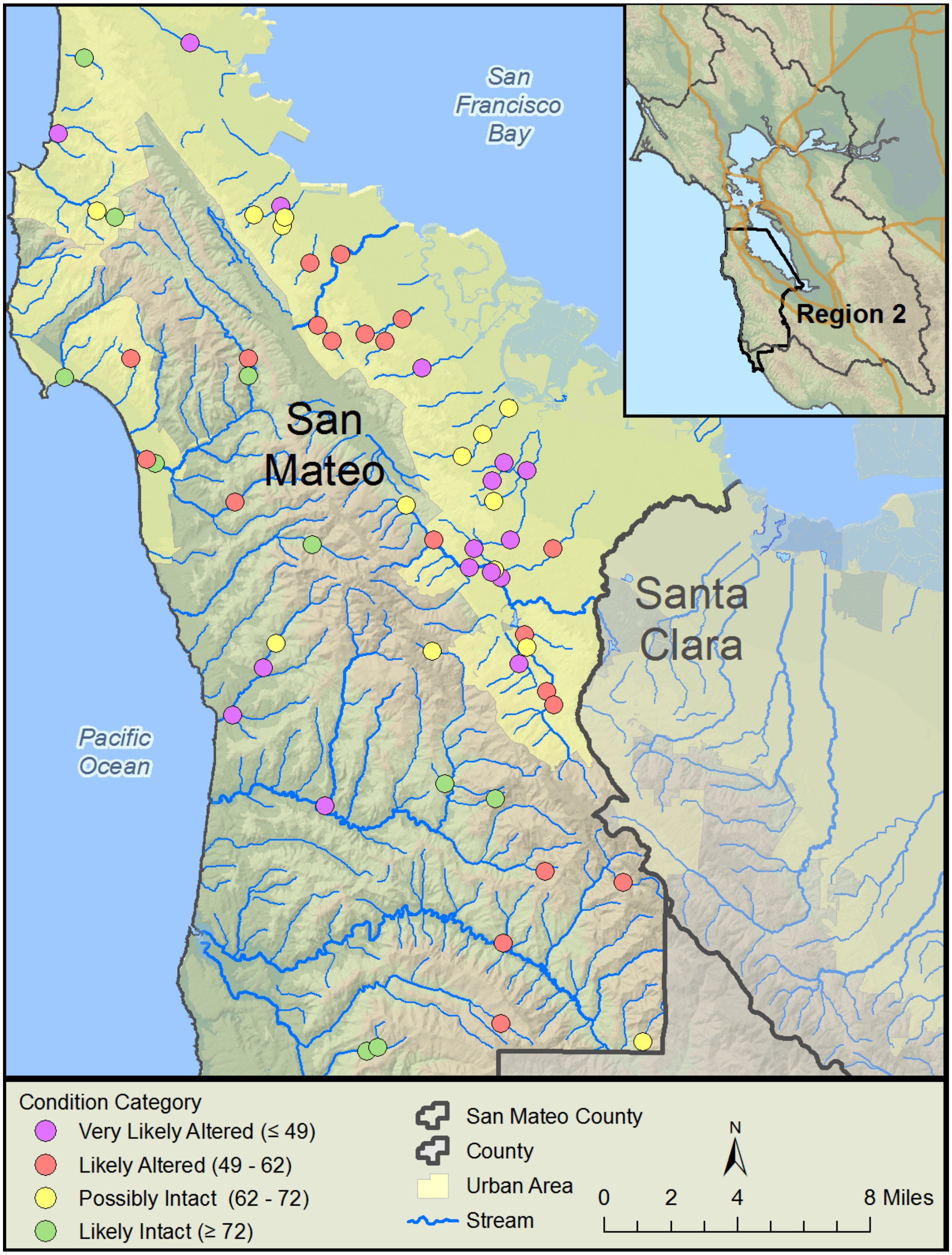

Figure 4-F. Biological condition based on D18 scores in San Mateo County.

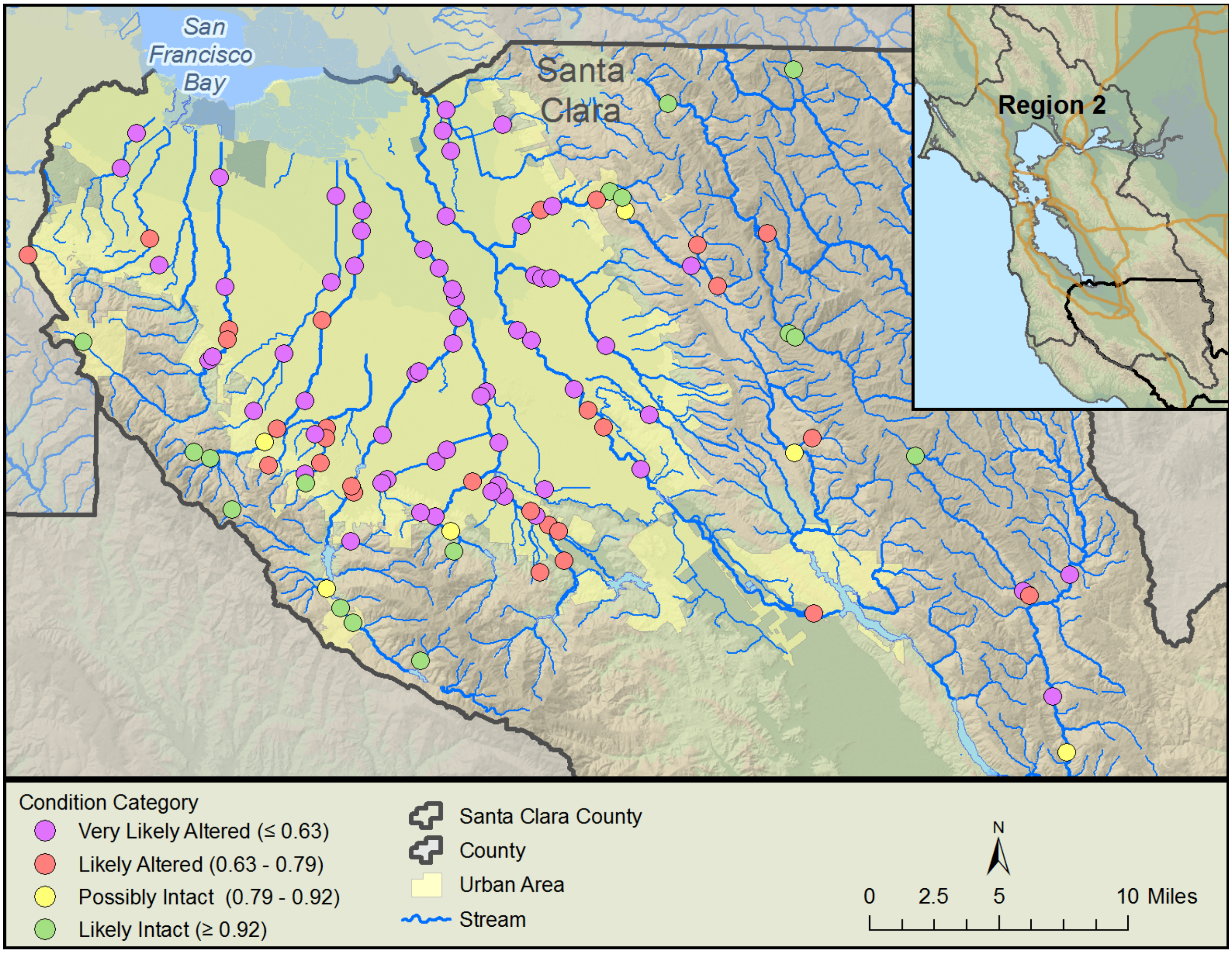

Figure 4-G. Biological condition based on CSCI scores in Santa Clara County.

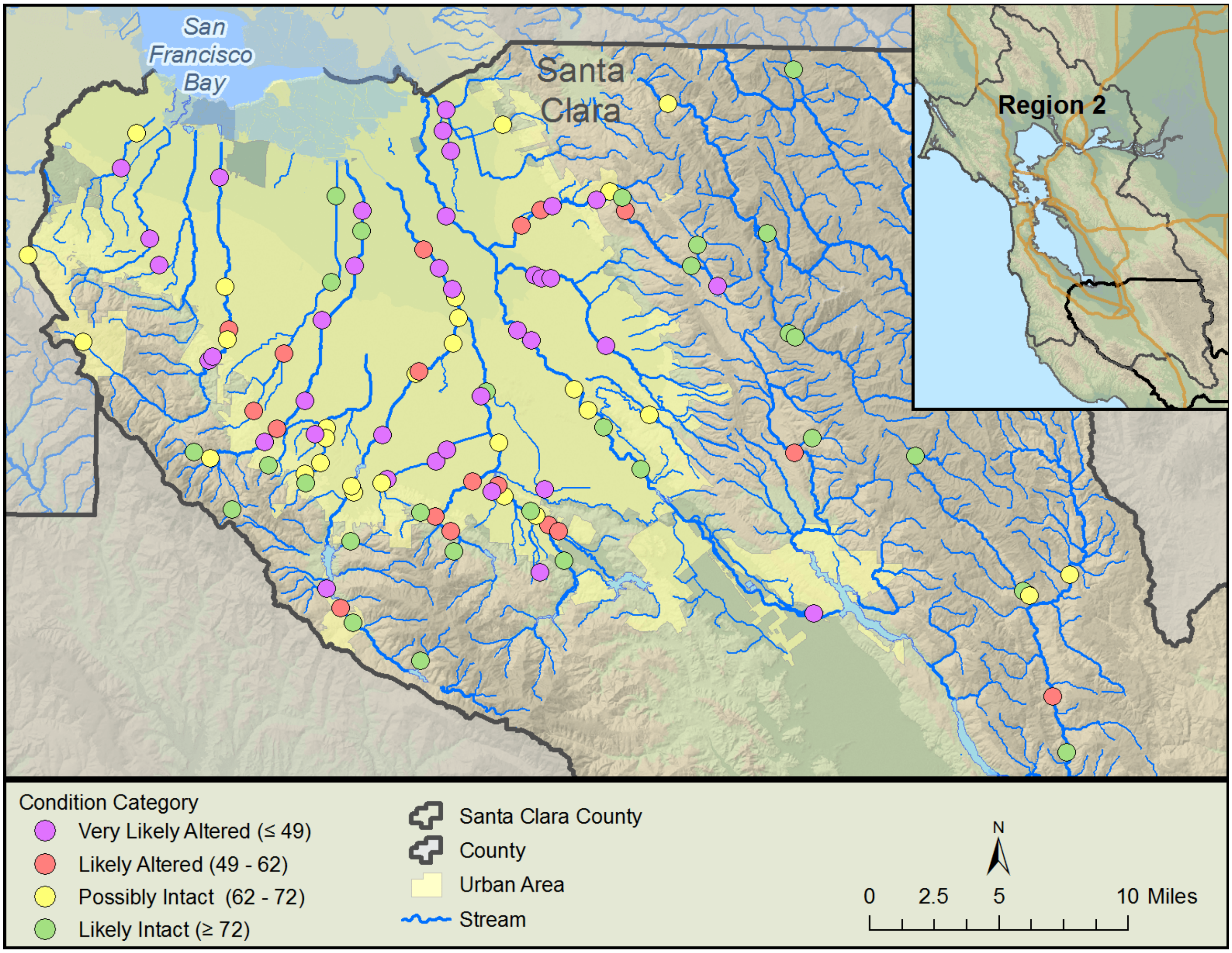

Figure 4-H. Biological condition based on D18 scores in Santa Clara County.

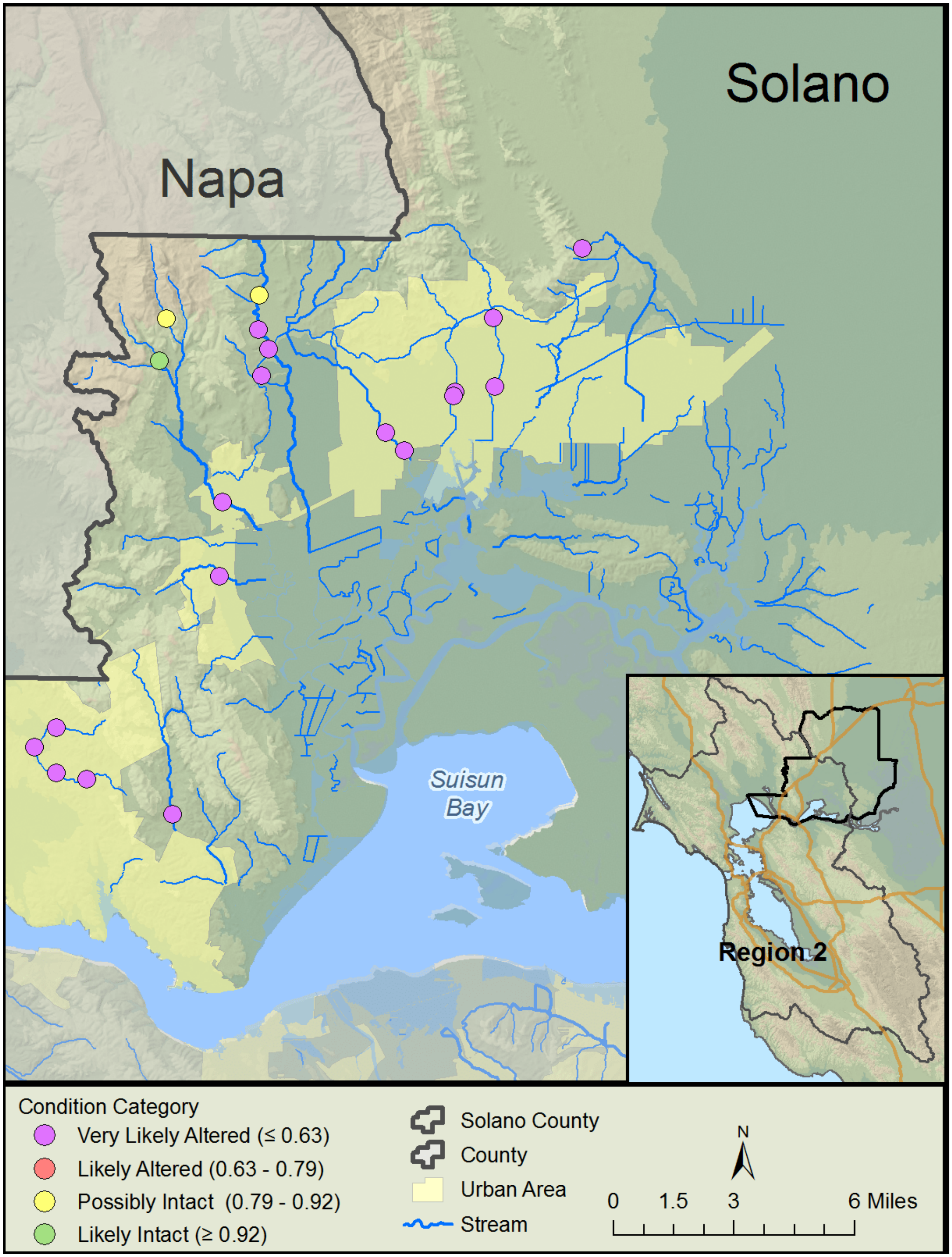

Figure 4-I. Biological condition based on CSCI scores in Solano County.

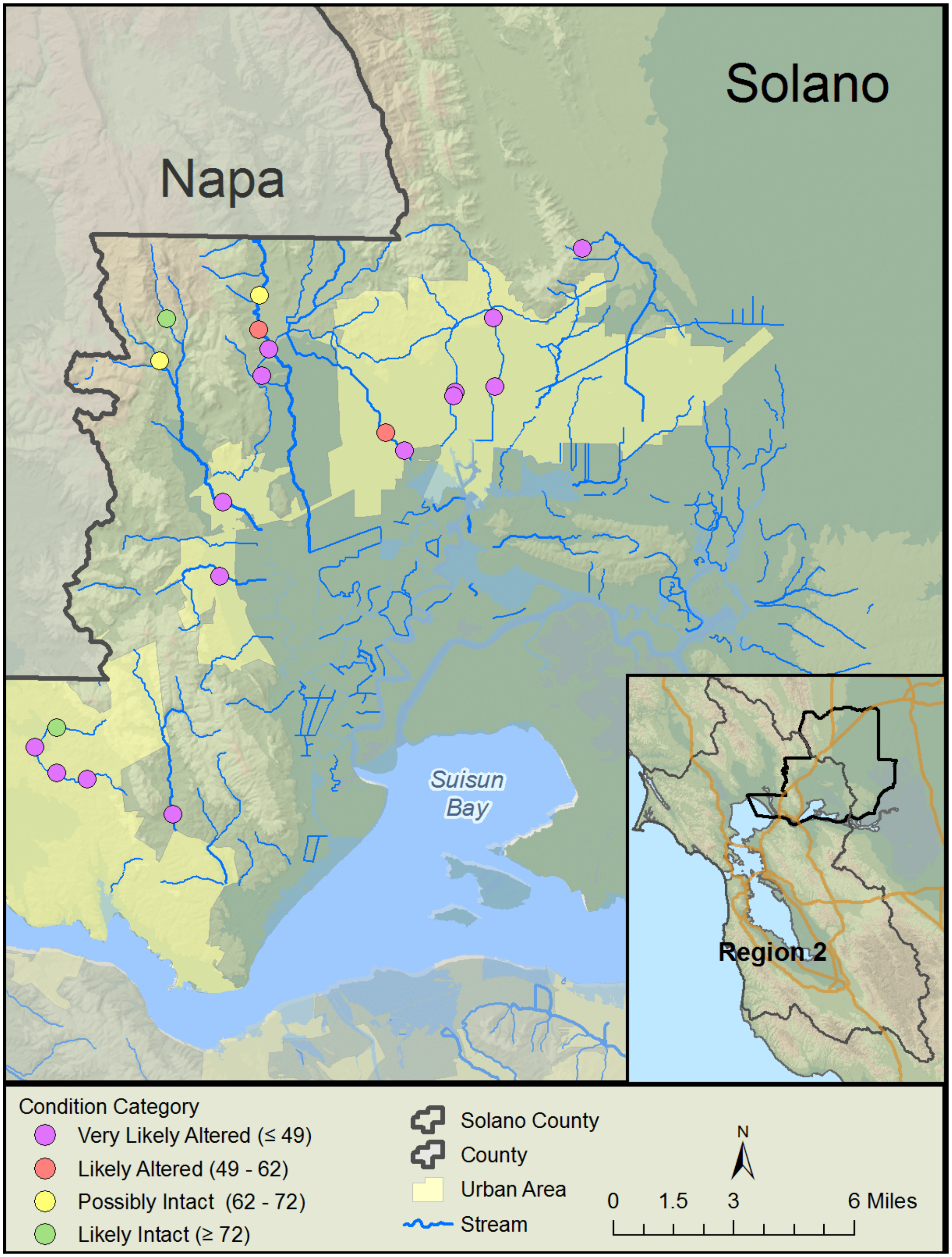

Figure 4-J. Biological condition based on D18 scores in Solano County.